

Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

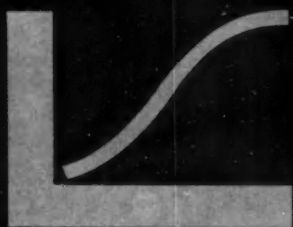
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APRIL 1961

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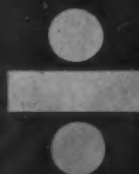
LINEARIZING



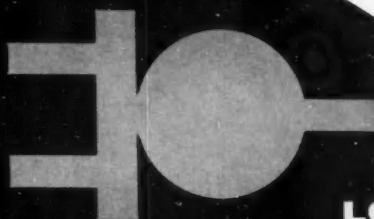
INTEGRATING



ARITHMETIC



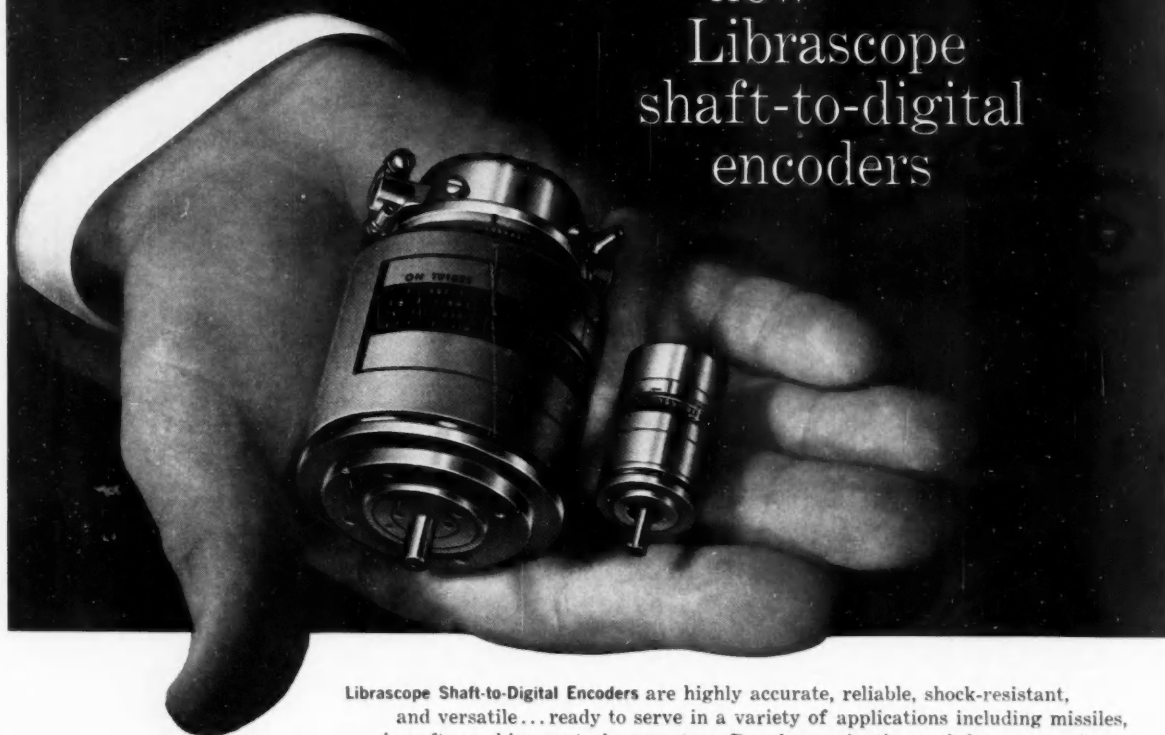
**Pneumatic
Analog
Computing**



LOGIC

NO OTHER LINE SO COMPLETE • 38 NEW ENCODERS • MAG
CODERS • 38 NEW ENCODER MODELS • SIZE 8 ENCODERS •
LINE SO COMPLETE • MAGNETIC ENCODERS • 38 NEW ENC
ODERS • SINE/COSINE ENCODERS • GRAY ENCODERS • 38 N
SELF-DECODING ENCODERS • NO OTHER LINE SO COMPLETE

new Librascope shaft-to-digital encoders



Librascope Shaft-to-Digital Encoders are highly accurate, reliable, shock-resistant, and versatile... ready to serve in a variety of applications including missiles, aircraft, machine control, computers, Doppler navigation and data processing. Accuracy that counts is the by-word of a Librascope Encoder... backed by the superior technology and reputation of one of the world's largest producers of Computers that Pace Man's Expanding Mind.

other popular Librascope encoders

Code	Model no.	Full scale capacity	Resolution per input shaft turn
Binary	773	13 bits	128 counts
	0-773	oil-filled unit for increased life	
Binary	710	10 bits	1024 counts
	707 (707D*)	7 bits	128 "
	713 (713D*)	13 bits	128 "
	717 (717D*)	17 bits	128 "
	719 (719D*)	19 bits	128 "
	0-713	oil-filled unit for increased life	
Self-Decoding Binary	740	10 bits	1024 counts
	723 (723D*)	2,000 counts	200 "
	724 (724D*)	20,000 "	200 "
	733 (733D*)	3,600 "	200 "
	734 (734D*)	36,000 "	200 "
B/C/D	735	360,000 "	200 "
	757-S**	4 quadrants per turn	7 bits per quadrant + limit 1
	758	4 quadrants per turn	8 bits per quadrant + limit 1
	758-S**	4 quadrants per turn	8 bits per quadrant + limit 1
	708	8 bits	256 counts
Sine/Cosine			
Gray			

*Contain isolation diodes for multiplexing

**Servo driven, hermetically sealed

new noncontact magnetic encoder

MODEL NO. 807

FEATURES:

Long life, high reliability, high speed, natural binary V-Scan readout.

SPECIFICATIONS:

Output Code: natural binary
Resolution: (per input shaft turn) 128 counts

Full Scale Capacity: 7 bits*

Speed: operating from 0 to 10,000 rpm

Life Expectancy: 20,000 hours at 4,000 rpm; 4 x 10⁹ revolutions

Starting Torque: 0.1 in.-oz. max.

Diameter: 2"

Length: 1 13/16"

Weight: 5 ounces

*ALSO AVAILABLE IN 13, 17, AND 19 BIT CAPACITIES.

new subminiature size 8 encoder

MODEL NOS. 787 & 793

FEATURES:

Low torque, low inertia, long life, high reliability, withstands severe environments.

SPECIFICATIONS:

Output Code: natural binary

Resolution: (per input shaft turn) 128 counts

Full Scale Capacity: 7 bits, 13 bits

Speed: operating 200 rpm, slew 600 rpm

Life Expectancy: 2 x 10⁹ revolutions at 200 rpm

Starting Torque: 0.5 oz.-in. maximum

Diameter: .750"

Weight: 3 ounces

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AVAILABLE
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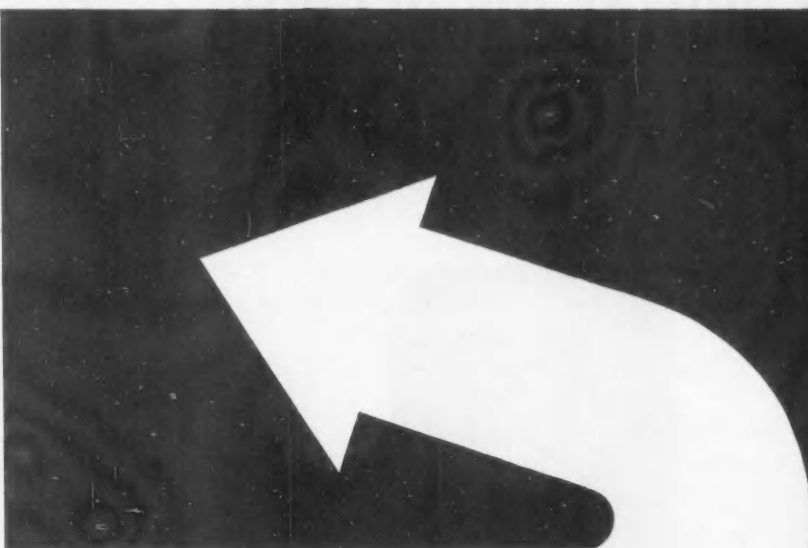


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John Schmidt
Engineering Employment

CIRCLE 233 ON READER SERVICE CARD



reject
ruinous
common mode noise

— even with
greatly unbalanced
source impedance!



KIN TEL's 114C Differential DC Amplifier eliminates ground-loop problems in grounded thermocouple and strain-gage measuring systems...gives you extremely accurate, stable, drift-free amplification of microvolt level signals in the presence of volts of common mode noise, irrespective of whether load and transducer are grounded or floating, balanced or unbalanced.

In brief, it is a *true* differential amplifier —

- the input is completely isolated from the output; both are completely floating and isolated from chassis ground.
- common mode rejection is 180 db at DC, 130 db at 60 cps, with up to 1000 ohms unbalance in the input circuit.

For further information on this exceptional amplifier, write today for detailed technical information or demonstration. There are Kin Tel engineering representatives in all major cities.

BRIEF SPECIFICATIONS

GAIN	10, 30, 100, 300, 1000 (plus vernier), accurate within 0.5%, stable within 0.02%
DRIFT	$\pm 2\mu\text{v}$ equivalent input for 40 hours.
INPUT Z	>30 megs (typically 50 megs)
OUTPUT Z	<0.25 ohm, DC to 500 cps
COMMON MODE REJECTION	180 db DC; 130 db at 60 cps with up to 1000 Ω unbalance, 120 db with up to 10,000 Ω unbalance
DC LINEARITY	$\pm 0.01\%$ of FS (10 volts)
PRICE	\$1000.00 in 195 cabinet (shown), \$875.00 without cabinet

5725 Kearny Villa Road, San Diego 11, California • Phone: BRowning 7-6700

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

IN HIGH-SPEED DIGITAL PROCESSING EPSCO DELIVERS ITS SPECIFICATION

Epsco's new solid-state S-2010 is a universal recording unit which accepts digital data from a wide variety of sources and records it on magnetic tape in any specified digital computer format.

Used in conjunction with a digital output data gathering system, the S-2010 automatically processes data into computer-acceptable form, saving hundreds of man-hours of data reduction and hundreds of computer translation hours in reprocessing raw data into a form suitable for high speed computation.

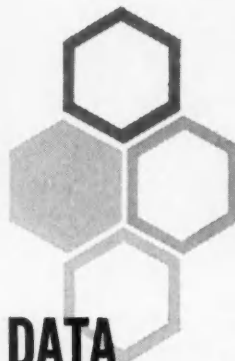
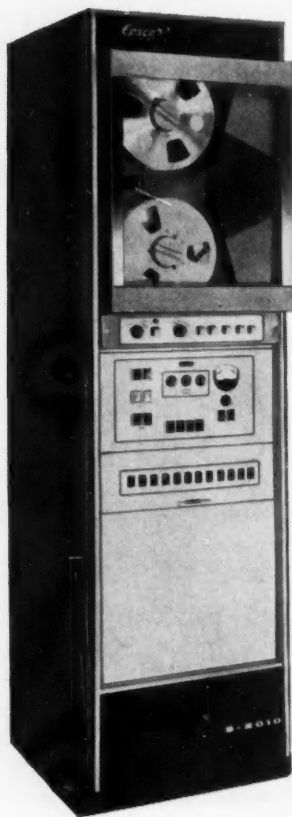
As the data recording rate of the S-2010 is limited only by the maximum tape writing rate of the particular computer format, multiple channel data acquired at high sampling frequencies can be processed directly onto computer format magnetic tape.

Twin, coincident-core memories permit continuous incoming data to be recorded as gapped computer-format records with no loss of data. The S-2010 automatically generates all necessary gaps, parity bits, end of record, end of file and finish marks.

The S-2010 — a transistorized version of Epsco's famous vacuum-tube S-2000 — offers much greater compactness (1 cabinet instead of 3) and increased reliability.

A complete spectrum of standard options can be added to the basic unit to create systems exactly tailored to specific needs.

Write or call Epsco for S-2010 brochure.



DATA REDUCTION PROBLEMS?

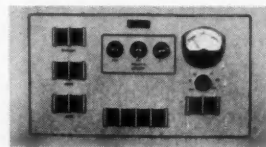
**NEW S-2010
COMPUTER FORMAT
RECORDER** automatically
records continuous incoming
data in gapped computer format.
Accepts any arbitrary data
asynchronously or synchronously
and at varying rates.

SPECIFICATIONS

Memory: Two, alternating, 5 μ sec coincident current core memories. Operates in push-pull mode for continuous data input; in tandem mode for intermittent data input. Plug-in memory modules of 256 characters each, available for expanding capacity. Choice of 256, 512, 768 or 1024 character capacity, in push-pull mode; up to 2048 character capacity in tandem mode. Choice of manual as well as automatic memory load. Memory verification read-out to line-at-a-time printer available.

Modes of Operation: Continuous or start-stop. Binary or BCD output. Variable record length control. Data programming. Self-checking test mode. On-line or off-line monitoring. Single or double memory operation. Data source control.

Construction: All solid-state, with quick-change, indexed plug-in circuit cards. Key logical elements have indicator lights, and all cards have test points brought out and identified.



Dimensions: Standard models, one standard 19-inch cabinet, 82" h x 22" w x 24" d.

Operating Environment: Temperature 32° F to 100° F, cooling by built-in ducting and blowers. Relative humidity: up to 90%. Altitude: up to 8000' above sea level.

Thermal Dissipation: 2250 BTU (mean).

Power Requirements: 105 to 125 volts A.C., 60 cps, single phase, approx. 6 amperes.



SYSTEMS

A Division of Epsco Incorporated, 275 Massachusetts Ave., Cambridge 39, Mass., UNIVERSITY 4-4950

Control ENGINEERING

APRIL 1961
VOL. 8 NO. 4

Published for engineers and technical management men who are responsible for
the design, application, and test of instrumentation and automatic control systems

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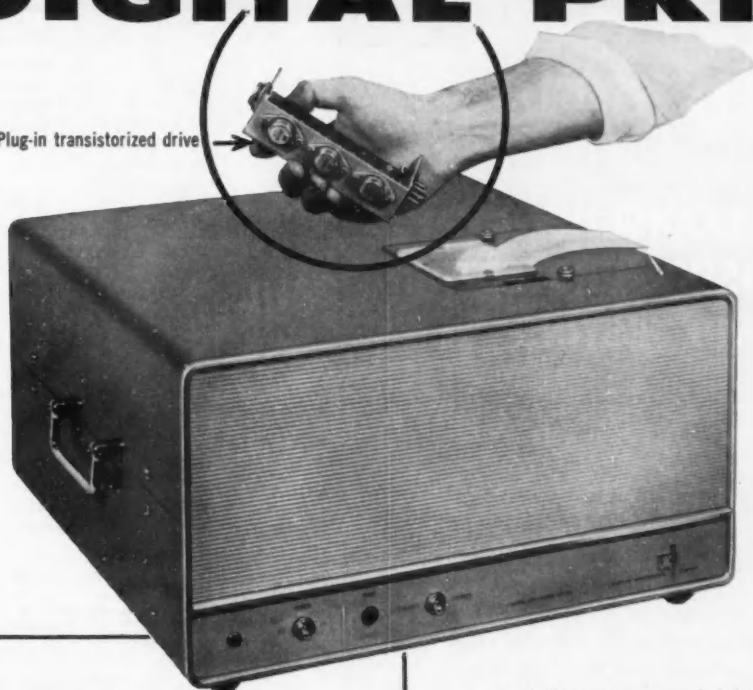
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solid state DIGITAL PRINTER

Plug-in transistorized drive



the 400 CT-

*The most versatile
digital printer
ever made*

SPECIFICATIONS

Printout capacity	6 digits standard.
Accuracy	determined by basic counting instrument.
Display time	0.2 seconds minimum, maximum controlled by the counter.
Weight	60 lbs.
Power requirements	115 volts $\pm 10\%$, 50-60 cps 25 watts
Dimensions	17" W x 8½" H x 16½" D. (Rack mounting available as option D.)
Warranty	One year on electronics; 1.5 million lines @ 4 lines per second on matrix; 10 million lines @ 4 lines per second on printer assembly, or 1 year, whichever occurs first.
Price	\$1350.00. Add \$10.00 for rack mount.

* 4 lines per second printout * Takes 1-2-2-4 or 1-2-4-8 four line code * No stepping switches * Operates from only 3 volt input * Parallel entry * Special options available including 10 line and analog output * 6 digit printout, up to 12 digits on special order * Rugged unitized construction * Completely compatible with CMC's new solid state frequency-period counters, and other types of transistorized counting equipment.

For a demonstration of this remarkable new printer and complete technical information, call your nearby CMC engineering representative or write to us direct. Please address Dept. 21.

CMC

9
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**Computer-Measurements
Company** A Division of Pacific Industries, Inc.

12970 Bradley Avenue • Sylmar, California

Phone: EMpire 7-2161

20A



THIS RUGGED TRANSDUCER ASSURES OVER-PRESSURE PROTECTION DURING GROUND TESTING

Here is the new high precision, corrosion-resistant instrument that rounds out CEC's line of strain gage transducers to provide coverage from ground through airborne testing.

This highly accurate, highly sensitive transducer is the 4-350, designed for ground testing... ground support equipment for missile launch and test facilities... and for industrial process instrumentation.

Its airborne counterparts are Consolidated's 4-328 and 4-329. Because all three have an output of the same integrity, it is now possible to use the new 4-350 on the ground and the two lighter weight units in the air without data "changing."

You'll find that all three transducers have the same general sensitivity and that most of their specifications are the same. Features of the 4-350 emphasize the protective characteristics necessary in ground developmental activities, where test parameter limits may not yet be fully established.

For more information, call your nearest CEC sales and service office or write for Bulletin CEC 4350-X1.

Transducer Division

CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

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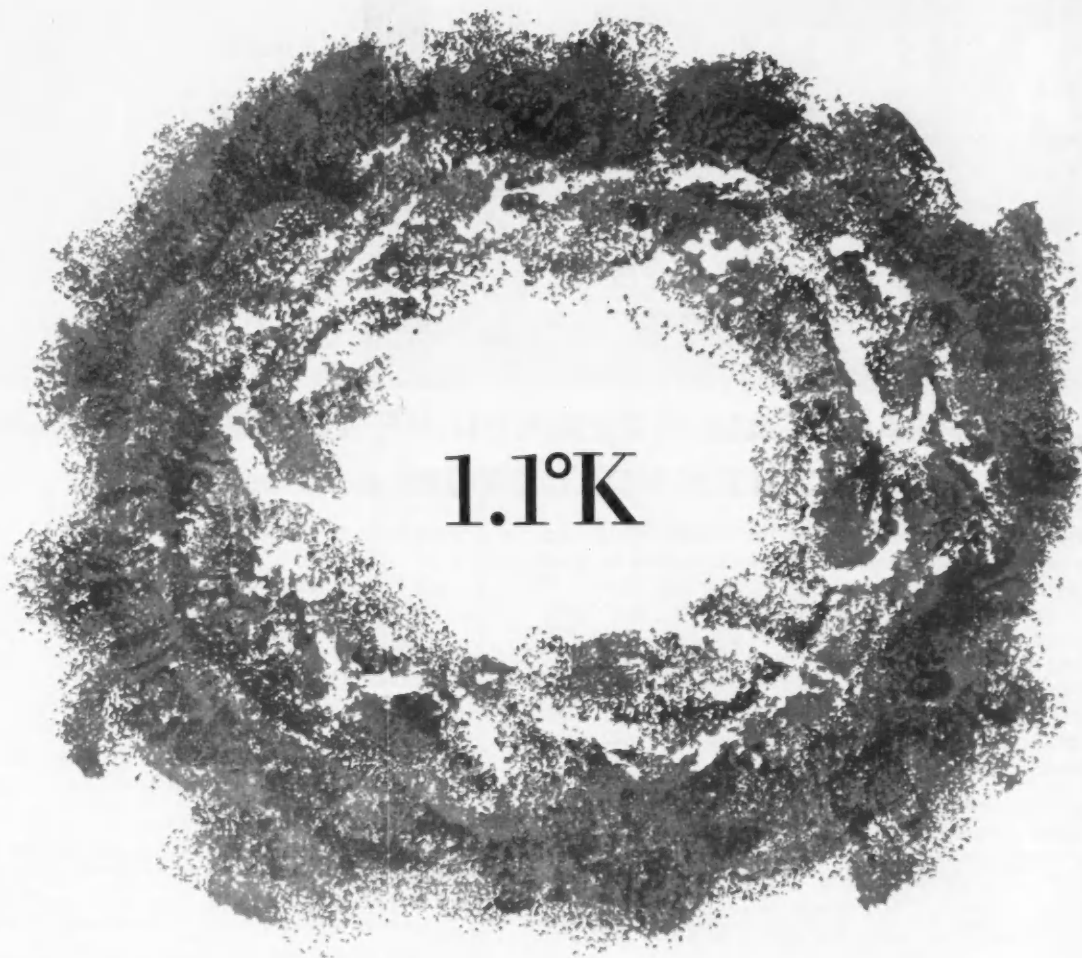
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1.1°K

Need help in measuring ultra-low temperatures?

A Honeywell transducer now in the works will accurately measure temperatures as low as 1.1° Kelvin. This important new development represents a single concrete result of Honeywell's specialized knowledge of the little-explored world of ultra-low temperatures. Both the knowledge and its implementation are at your disposal, in any degree from basic research to custom design of equipment to your own specifications. If you're now involved with liquid hydrogen, liquid helium, superconductivity of metals—or any project that may call for measurement of temperatures below the range of your present means—Honeywell can help. Write to John Moxness, Minneapolis-Honeywell, 151 E. Hunting Park Avenue, Philadelphia 24, Pa.

Honeywell



First in Control

SINCE 1886

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world, Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

APRIL 1961

CIRCLE 7 ON READER SERVICE CARD

7

PRODUCTION QUANTITY TI SIL

MAXIMUM 12 nsec t_{on}

MAXIMUM 40 nsec t_{off}

$V_{CE(sat)}$ PRACTICALLY INSENSITIVE TO TEMPERATURE... CONSTANT 1 VOLT FROM -55 to $+170^{\circ}\text{C}$

The fastest silicon switcher in the industry! Design today with Texas Instruments new 2N743 and 2N744 silicon epitaxial transistors and get *two-times faster switching than possible from any other commercially available silicon transistor!* This outstanding new epitaxial series gives you an optimum combination of ultra-fast switching times, temperature-stable R_{CS} , very low collector capacitance, and high f_T , to make the 2N743 and 2N744 *ideal for application in current ranges from 1 to 100 ma.*

Utilize the low R_{CS} /high current characteristics of these new epitaxial units to *replace large size medium-power transistors* and cut your overall switching times as much as two-thirds. Cut cost and reduce the complexity of your NOR logic designs with the new TI 2N743 series — these new epitaxial units give you

a guaranteed I_{CEX} of 30 μa at a V_{CE} of 10 volts and V_{BE} of 0.35 volts to eliminate additional circuits previously required for an I_{B2} turn-off source in your computing systems.

Apply the new 2N743 and 2N744 to your designs today and get *guaranteed d-c betas at three current levels.* The 2N744 gives you a guaranteed h_{FE} of 20 at 1 and 100 ma and a 10-ma beta spread of 40 to 120, while the 2N743 features a minimum h_{FE} of 10 at 1 and 100 ma, and 60 maximum at 100 ma.

New TI 2N743 and 2N744 silicon epitaxial transistors are immediately available from distributor stocks or in mass production quantities at prices competitive with conventional silicon mesa and micro-alloy transistors.

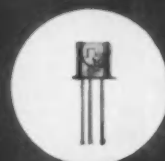
Compare the 2N743 and 2N744 with conventional transistors!

Parameter	Approx. Test Conditions	TI 2N743	TI 2N744	2N834	2N706B	2N708
$T_s(\text{nsec})$	$I_{B(1)} = -I_{B(2)} = I_C = 10 \text{ ma}$	14	18	25	25	25
$t_{on}(\text{nsec})$	$I_{B(1)} = 3 \text{ ma}$ $I_{B(2)} = -1 \text{ ma}$	11 (TYP)	10 (TYP)	35	40	35
$t_{off}(\text{nsec})$	$I_C = 10 \text{ ma}$	22 (TYP)	25 (TYP)	75	75	75
$t_{on}(\text{nsec})$	$I_{B(1)} = 40 \text{ ma}$ $I_{B(2)} = -20 \text{ ma}$	12 6 (TYP)	12 6 (TYP)	NO SPEC	NO SPEC	NO SPEC
$t_{off}(\text{nsec})$	$I_C = 100 \text{ ma}$	40 18 (TYP)	45 23 (TYP)	NO SPEC	NO SPEC	NO SPEC
$V_{CE(sat)}$	$I_B = 1 \text{ ma}$ $I_C = 10 \text{ ma}$ $T_A = +170^{\circ}\text{C}$	0.35 v	0.35 v	No High Temp. Guarantee (0.19 v MAX. @ 25°C)	No High Temp. Guarantee (0.4 v MAX. @ 25°C)	No High Temp. Guarantee (0.4 v MAX. @ 25°C)
I_{CEX}	$V_{CE} = 10 \text{ v}$ $V_{BE} = +0.35 \text{ v}$ $T_A = 100^{\circ}\text{C}$	30 μa	30 μa	No Guarantee	No Guarantee	10 μa (MAX.) @ $V_{BE} = +0.25 \text{ v}$ $V_{CE} = 20 \text{ v}$ $T_A = +125^{\circ}\text{C}$

NOTE: All limits are max. unless otherwise noted.

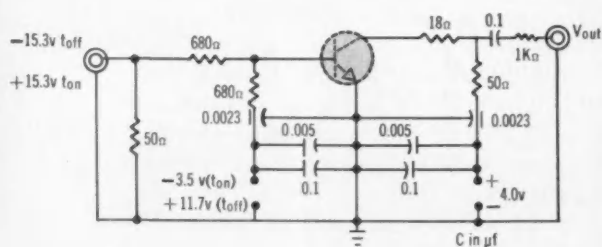
ICON EPITAXIAL TRANSISTORS

@100 ma



MAKE YOUR OWN COMPARISON FROM THESE TYPICAL CIRCUITS

50-ma SWITCHING CIRCUIT



USE THE TI 2N743 TO SWITCH IN 1/3 THE TIME!



2N706

$t_{on} = 10 \text{ nsecs}$
 $t_{off} = \frac{50}{60} \text{ nsecs}$



2N743

$t_{on} = 7 \text{ nsecs}$
 $t_{off} = \frac{15}{22} \text{ nsecs}$

USE THE TI 2N743 TO DOUBLE POWER OUTPUT AND EFFICIENCY!



2N706

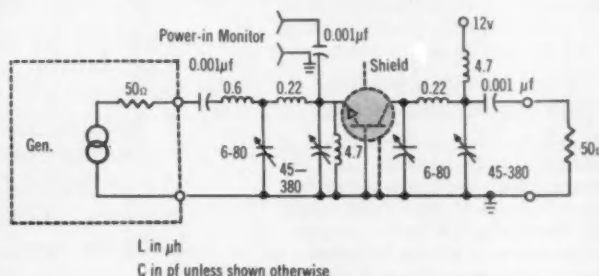
$P_{out} = 225 \text{ mw}$
 $Eff = 32\%$
 $P.G. = 6 \text{ db}$



2N743

$P_{out} = 500 \text{ mw}$
 $Eff = 65\%$
 $P.G. = 6 \text{ db}$

70-mc POWER AMPLIFIER



INDUSTRY'S BROADEST LINE OF TRANSISTORS
SEMICONDUCTOR-COMPONENTS DIVISION

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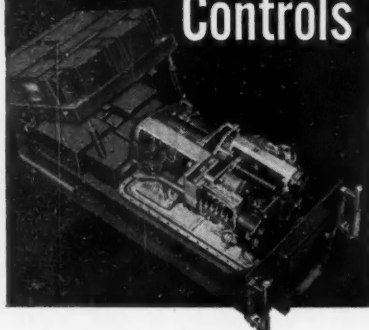
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CIRCLE 9 ON READER SERVICE CARD

Automatic Sequencing Controls



AiResearch's design and manufacturing capability covers many types of automatic sequencing controls such as those for missile ground checkout, controlling drone and missile flight profiles, and automatic elevation and leveling of radar antennas and missiles.

Above is an AiResearch sequence controller for cabin temperature of a jet airliner. It assimilates 25 sensor element inputs and supplies command signals to 18 amplifier channels. Consisting of servo-operated potentiometer cards, cam switch programmer and other electromechanical components, it is another example of AiResearch's over-all ability to design and produce intricate and complicated servo systems.

The most experienced company in the development and production of control systems for airborne and ground use, AiResearch is an industry leader in electromechanical systems and components of all types for aircraft, ground handling, ordnance and missile systems.

OTHER ELECTROMECHANICAL COMPONENTS AND SYSTEMS

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THE GARRETT CORPORATION

AiResearch Manufacturing Division

Los Angeles 45, California

SHOPTALK

Young defeats fog and strike, gets his story

What doesn't get into a CONTROL ENGINEERING story sometimes makes interesting reading. Take for example the special news report on Air Traffic Control starting on page 24. When News Editor Lew Young started traveling to round up the details for it he ran smack into the airline engineers strike, found himself grounded. By riding trains and driving his sturdy Renault he managed to make a number of key visits at points on the East Coast.

When the strike ended, Editor Young, who favors traveling by plane, again found himself reduced to riding trains by some of the worst fog that has hit the East Coast in years, emphasizing the great need for some kind of all-weather take-off and landing system.

Back in New York, Lew rushed his story through the typewriter to report good news: as a first step toward meeting the traveling public's needs, the FAA will probably approve an automatic system for cargo planes this year.

Stalwart Florence

Technical editors scouring the highways, flyways, and byways generating and creating useful news and engineering articles is only part of our story. Article execution—getting the type set, processing illustrations, and generally making sure that article as it appears in print is just the way the author, the editor, and the art director visualized it—is the responsibility of Editorial Assistant Florence Baxley. Unwavering in her partisanship in producing a good magazine, to state her job succinctly, Flo manages the managing editor.

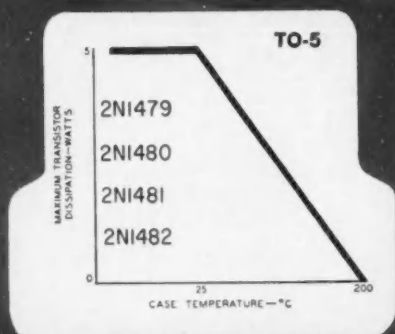
Processing our data for the inquiring reader

We're glad to serve you, of course, but there's no use doing things the hard way, what with the volume of Readers Service Cards building up. Each card contains a host of circles, and for each circle the reader's name must go on another list. A complicated, time-consuming procedure. Well, perhaps you would like to know that we practice what we preach. We've switched to automatic data processing to handle your inquiries. Data printers now spew out lists and mailing labels for speeding more good information to you.

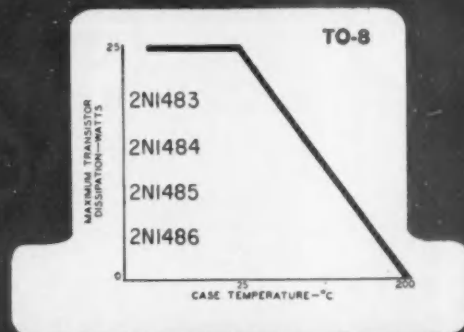
Positive response on positive feedback

Last November we published Bill Scharf's article: Don't Overlook Positive Feedback. Bill's piece made a hit. In force, readers asked for author's notes we didn't print on positive feedback underdamped second order compensation. Interested? Write for one of the few remaining copies.

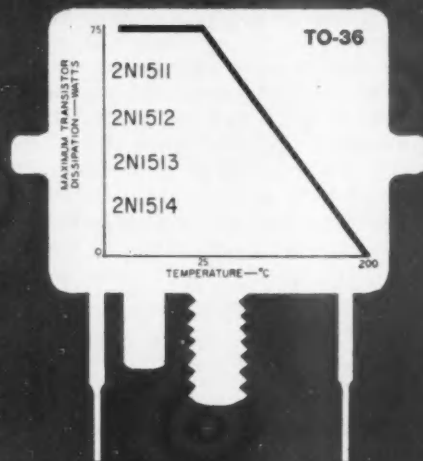
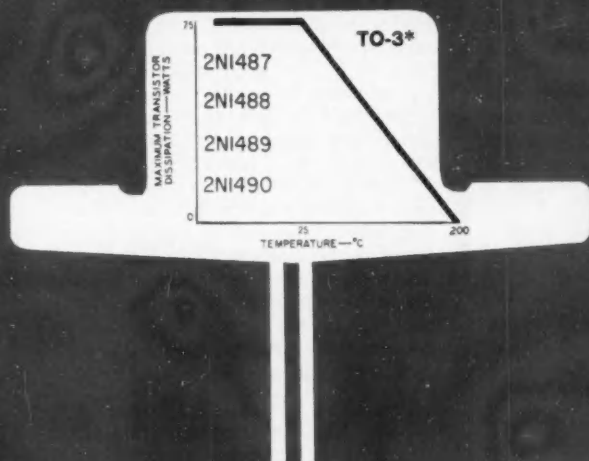
MEDIUM POWER



INTERMEDIATE POWER



Upgrade Industrial Circuit Designs With These RCA 200°C Silicon Power Transistors



HIGH POWER

New high-temperature ratings on 16 popular RCA silicon transistors for improved performance in military and industrial applications at no increase in price

MAXIMUM RATINGS, Absolute-Maximum Values:						
	2N1479 2N1481	2N1480 2N1482	2N1483 2N1485	2N1484 2N1486	2N1487 2N1489 2N1511 2N1513	2N1488 2N1490 2N1512 2N1514
COLLECTOR-TO-BASE VOLTS	60V	100V	60V	100V	60V	100V
COLLECTOR-TO-EMITTER VOLTS With base open (sustaining voltage)	40V	55V	40V	55V	40V	55V
With emitter-to-base reverse biased ($V_{BE} = 1.5$ volts)	60V	100V	60V	100V	60V	100V
EMITTER-TO-BASE VOLTS	12V	12V	12V	12V	10V	10V
COLLECTOR CURRENT (Amps.)	1.5a	1.5a	3a	3a	6a	6a
EMITTER CURRENT (Amps.)	1.75a	1.75a	—3.5a	—3.5a	—8a	—8a
BASE CURRENT (Amps.)	1a	1a	1.5	1.5a	3a	3a
TRANSISTOR DISSIPATION (Watts) At case temperature of 25°C	5w	5w	25w	25w	75w	75w
At case temperature of 100°C	2.85w	2.85w	14.1w	14.1w	43w	43w
CASE TEMPERATURE RANGE (°C) Operating and Storage	—65 to +200°C					

*Similar to TO-3

RCA SEMICONDUCTOR & MATERIALS DIVISION... FIELD OFFICES: EAST: Newark, N. J., 744 Broad Street, HUmboldt 5-3900 • Syracuse 3, New York, 731 James Street, Room 402, GRanite 4-5591 • NORTHEAST: Needham Heights 94, Mass., 64 "A" Street, Hillcrest 4-7200 • EAST CENTRAL: Detroit 2, Mich., 714 New Center Bldg., TRinity 5-5600 • CENTRAL: Chicago, Ill., Suite 1154, Merchandise Mart Plaza, WHitehall 4-2900 • Minneapolis, Minn., 5805 Excelsior Blvd. • WEST: Los Angeles 54, Calif., P. O. Box 54074, RAymond 3-8361 • Burlingame, Calif., 1838 El Camino Real, OXford 7-1630 • SOUTH: Orlando, Florida, 1530 Edgewater Drive, Suite 1, GAlden 4-4768 • SOUTHWEST: Dallas 7, Texas, 7905 Empire Freeway, Fleetwood 7-8167 • GOVERNMENT: Dayton, Ohio, 224 N. Wilkinson St., BAldwin 6-2366 • Washington, D.C., 1725 "K" Street, N.W., FEderal 7-8500.

Here are 16 RCA N-P-N diffused-junction silicon power transistors immediately available in quantity, to meet the more exacting performance requirements of today's industrial and military equipment.

Check out the remarkable improvements these RCA high-performance industrial transistors now offer:

- 14 percent increase in maximum operating temperatures — up to 200°C.
- Up to 66½ percent increase in dissipation capability — up to 75 watts.
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- Up to 50 percent increase in minimum beta.
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All of these features provide greater flexibility in the design of power switching devices such as dc-to-dc converters, inverters, choppers, solenoid and relay controls; oscillators, regulators, and pulse amplifiers; and class A and class B amplifiers for servo and other audio frequency applications.

Call your RCA Semiconductor Field Representative today for full particulars on these silicon power types. For your copy of the new RCA 25-page Application Guide on RCA Silicon Power Transistors, send 50 cents to RCA Semiconductor and Materials Division, Commercial Engineering, Section D-56-NN, Somerville, N. J.

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The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

FISCHER & PORTER

INSTRUMENTS THAT MEASURE AND CONTROL FLOW, TEMPERATURE, PRESSURE, &c., &c., &c. have established their reputation for superiority against all competitors through the years. In the realm of fluid flow measurement, Fischer & Porter Company is the

ONLY COMPLETE FLOWMETER HOUSE

We solicit your attention to the outstanding examples noted herewith.

THE HANDIEST GUIDE TO THE VARIOUS AND SUNDRY METHODS PRESENTLY AVAILABLE FOR MEASURING FLOW

It has been our pleasure and profit over the years to aid and assist divers engineers in the estimable task of selecting the one—nay, the *only* device best suited to measuring a given flow. But truly, the years have added, the devices have multiplied, and the task of selection has grown ever more complex. As a result, the “handy” guides, so reminiscent of an earlier day have grown less handy all the time. Let us see how handy we can be.

LESSON I

There are but four major types of flowmeters.

1. VARIABLE-AREA



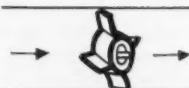
2. VARIABLE HEAD



3. OBSTRUCTIONLESS



4. INTEGRATING



LESSON II

In order to be as handy as possible, we shall limit our discussion of the advantages of the four basic types to a single characteristic benefit.

1. Variable-Area: linear scale
2. Variable Head: flexibility

3. Obstructionless: obstructionless
4. Integrating: accuracy

LESSON III

This lesson is of the most importance as it concerns the various factors necessarily involved in the judicious selection of flowmetering devices. These primary and critical factors are: fluid property limitations, application, installation and economics. We need not go into detail on these factors since our Bulletin 91-119, a veritable gem of condensation, reviews all of these factors in the short space of only six pages. There is a limit as to how short and “handy” such a guide can be.

If you are one of those, and there are many, who philosophically opposes all “handy” guides, then we need only remind you that we make all of the four major types. Indeed, we are the only company to do so. We also wish to state that we use a wide variety of materials to construct these meters including many readout and process control devices. Our laboratories include the finest and most advanced flow measuring and calibrating equipment. A call to our field engineers can save you trouble and bring you a firm recommendation unencumbered by bias or prejudice.

TO THE RIGHT



is a sampling of some outstanding examples of each type of meter in our flowmetering line.

Variable-Area Flowmeters

Fischer & Porter has indeed made its mark in lands far and wide as the leading manufactory of variable area meters, finding itself pleasantly faced with such wide acclaim for ease of use and simplicity that it defies description. Yea, and to no surprise. Indeed our people have labored unceasingly to INTRODUCE EVERY MAJOR ADVANCE in this noble form of flowmetering, to wit: the glass tube that allows viewing the rate of flow directly; the bead-guide and Tri-Flat meter for matchless float stability; the predictable float which simplifies calculations; the metal tube for high pressures and temperatures.

Frictionless! Foolproof!

—herald the fortunate employers of the MAGNABOND coupling developed by Fischer & Porter for detecting the linear motion of the float, with abundant power to operate a multitude of accessories for recording, transmitting, totalizing and controlling. The ingenious detection system employs permanent magnets sealed into a non-magnetic, corrosion-resistant extension unit, and is widely used in conjunction with the popular FLOW-RATOR meters.

The NEW, ALL NEW MAGNARATOR

with

FLOW INDICATOR
and

PNEUMATIC TRANSMISSION



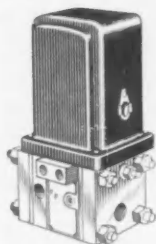
This amazing apparatus is distinguished as the TRUE in-line, through-flow meter. Of great joy to installation and maintenance men alike, no extension is needed and there are no

CONTROL ENGINEERING

crooks, crannies or corners where material can collect. The MAGNARATOR, kin to the extension-type MAGNABOND flow transmitter, is lofted to great heights of applicability by a new magnetic coupling principle. It measures, indicates and transmits pneumatically with a linear output signal!

{ Variable Head Flowmeters }

...featuring the



DP TRANSMITTER

by the wizards of Warminster

FISCHER & PORTER

Outwits PULSATION!

Outwits CORROSIVE FLUIDS!

Outwits STEAM TRACING PROBLEMS!

This popular differential pressure transmitter undeniably supports its claim as being the best in the world. Since it was first presented to the metering public its success has been remarkable. WHY? Its superiority over all others is substantiated by the FACTS OF ACTUAL USE!

ASTOUNDING ADVANTAGES

found in no like instrument
ADJUSTABLE DAMPING in the differential sensing system, Gentlemen, which is where it should be. We warrant there to be no other method that lets you measure PULSATING flow without zero shift, PHANTOM signals, diaphragm fatigue or premature parts failure.

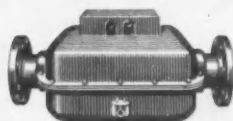
NEW METALS & ALLOYS such as Tantalum, 316 Stainless and Monel are STANDARD materials of construction for the sealing DIAPHRAGMS. Other "wetted" parts are fabricated from 316 Stainless, Monel, Nickel and Hastelloy C—as you desire. A perfectly sealed measuring chamber filled with the celebrated silicone oil PROTECTS ALL WORKING PARTS.

INTEGRAL STEAM TRACED PROCESS FLANGES, available from our shipping shelves, enables one to conveniently heat process connections to prevent fluids from "freezing"—all without TROUBLE-SOME AND EXPENSIVE lagging and tracing in the field.

{ Obstructionless Flowmeters }

THE JUSTLY CELEBRATED MAGNETIC FLOWMETER

OF FISCHER & PORTER
one of the very best instruments ever invented



An unobstructed length of pipe that accurately measures the flow of even the least conductive fluids by the Invisible MAGNETIC FIELD. Extends the range of accurate flowmetering to heretofore unbelievable limits. A rangeability of 3000:1! Measures the flow of any liquid with a conductivity of no less than 0.1 micromho per centimeter.

Measures flow in EITHER DIRECTION and without auxiliary equipment. Handily provides full scale recording of ANY FLOW RATE from 1 to 30 feet per second at the TURN OF A DIAL.

Coupled with a

Fully Transistorized Recorder

Years ahead of its time! An instrument of the future which you can profitably use today. The new recorder incorporates compact transistorized circuits which have reduced space requirements incredibly. Now the entire instrument is contained in a SINGLE DEPTH CASE. No black boxes to add. All amplifiers are mounted on plug-in cards.

Gentlemen, the Magnetic Flowmeter itself represents the GREATEST ADVANCE in flowmetering in the last quarter century!

YOUR ATTENTION INVITED!



STATE YOUR PLEASURE, GENTLEMEN!

To better acquaint our public with the BENEFITS and ADVANTAGES of our UNIQUE products we have caused to be printed handsome booklets for the general edification. We will gladly post to you a selection of these works upon your application. It will only require an expression as to the type of meter(s) of interest, that is Variable-Area, Variable Head, Obstructionless and Integrating and also our "handy" Guide (91-119). We are your obedient servants in this as in all other matters.

FISCHER & PORTER CO.

WARMINSTER, PENNSYLVANIA & TORONTO, CANADA

A world-wide INSTRUMENT COMPANY with plants in Australia, England, France, Germany, Holland, Mexico, as well as the U.S.A.

{ Integrating Flowmeters }



TURBINE METER

Here is the zenith in flowmetering of the greatest accuracy over a wide range, designed for the most fastidious users. Each and every revolution of the bladed rotor in the TURBINE METER signifies the passage of a definite unit of fluid volume with an ELECTRICAL pulse. The total number of counts is proportional to the total volume of FLUID PASSING THROUGH the meter.

NEW! NEW! NEW



TRANSISTORIZED READOUT DEVICES

The Turbine Meter can be linked with any of an unbelievable number of Readout Devices to oversee your process operations. Exemplary devices, utilizing the most up-to-date transistorized electronic components and techniques can indicate, totalize, record and control.

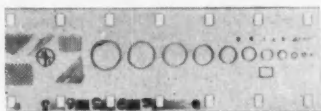
Continuous In-Line Blending NOW A FACT

Triumph at last. To the marriage of the amazing Turbine Meter and Marvelous Electronic Readout Devices goes a new distinction. Together they have brought to reality a truly Continuous IN-LINE BLENDING System for blending of two or more fluids. This combination offers to you many other solutions for conquering DIFFICULT & DEMANDING & COSTLY flowmetering operations.

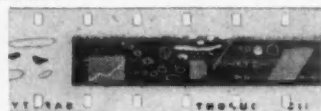


NARROW-CHANNEL PHOTOGRAPHY

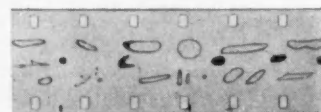
For people with the problem of photographing the interior of long, narrow channels, Kollmorgen has developed unusual devices capable of recording on film channels as narrow as $\frac{1}{32}$ of an inch.



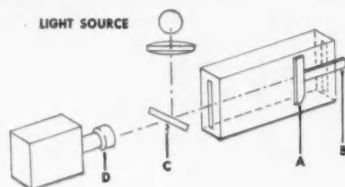
Above, actual size, is a test film of circles and numerals placed within a $\frac{1}{32}$ -wide channel.



Above is a panoramic view of a continuous section of the same film... with marks enlarged 8x.



Pitting, corrosion, fracture and other defects of interior walls can be continuously recorded with full-dimensional accuracy... of exceptional value in quality control operations.



The secret of our insight: A highly precise 45° mirror (A), mounted on a reed (B), is inserted in one end of the channel. A beam splitter (C) directs a powerful light into the channel from the opposite end which is reflected by the mirror onto the sidewall. The photographic leg of the system receives the image from the channel mirror and through the beam splitter. A camera objective (D) focuses the image on the film. The channel is advanced by a carriage in precise synchronization with the advance of film. Result: a continuous, clear photographic record of the entire channel.

Various modifications of this device have been applied to channels up to six feet long. For longer and wider channels we have designed a miniature self-propelled camera, mirror and light source capable of presenting a continuous image on film with resolution sufficient to reveal scratches and hair-line cracks smaller than .010 inch.

If you need special insight on "in-accessible" interiors, or information on other unusual applications of optics/electronics/mechanics—let's talk it over.

Write Dept. 5-4



KOLLMORGEN
CORPORATION
NORTHAMPTON, MASSACHUSETTS

FEEDBACK

Reliability numbers game grows

TO THE EDITOR—

In reading your issue for December 1960, I was very interested in the article ("Rebuttal by the Military") by Major William L. Still on page 77.

On page 81 he states that there would be an overall reliability improvement by a factor of 140 if the engineering and electronic parameters were improved a hundred times and the maintenance only doubled.

As I see it, the following would be the case out of 1,000 failures:

Failures	Now	Improved as stated
Electronic	333.3	3.33
Engineering	333.3	3.33
Maintenance	333.3	166.67
	1,000	173.33

If my arithmetic is correct, the factor of improvement is 5.76923077 and not 140 as stated. It would appear that Major Still is figuring on a 100 times improvement in all three factors.

Lawrence Collins
Damage Assessment Officer
Civil and Defense Mobilization
Battle Creek, Mich.

Don't confuse transient reliability with steady state reliability; Major Still explains the difference here. Ed.

TO THE EDITOR—

If one continues the mistakes made by the authors (Steele and Kircher, The Crisis We Face—Automation and the Cold War) and extrapolates present operating conditions to predict what will happen to Minuteman, both they and Colonel Collins are correct in the effect of maintenance on the total picture. However, in order to reduce the problem to simple arithmetic, you must use one of two possible boundary conditions of a differential equation which in its complete form is rather complicated. I chose the initial conditions as being more representative; they chose the steady state condition. The authors treat the three classes of failure as independent probabilities. This can only occur after the system has stabilized, and all components have failed and been repaired at least once. The initial conditions for the problem are defined by a state where all components are new and none have failed for any reason. Since now all parts are functional, and none have been repaired, there can be no failure rate

chargeable to maintenance. Actually, the failure rate due to maintenance forms a conditional probability that can only be imposed after failures due to other causes have occurred.

Let's look at a simplified transient solution to the problem and see which more truly represents the case. The fact that both the authors and I talk in terms of MTBF (mean time between failures) implies that we both accept the exponential distribution to define P_f (the probability of failure). The solution to this equation is

$$P_f = \int_0^t \frac{1}{MTBF} e^{-\frac{t}{MTBF}} dt \quad (1)$$

$$\text{thus, } P_f = 1 - e^{-\frac{t}{MTBF}} \quad (2)$$

Using the authors' figure of 10,000 years as a MTBF for individual parts, and an average of fifty parts per printed circuit card (which would be the lowest maintainable unit), we find that the MTBF per card is 10,000 years divided by fifty parts per card, or 200 years per card.

If we take the expected operational life of the system to be ten years, and use these numbers in equation 2, we have

$$P_f = 1 - e^{-0.05} = 0.049$$

Thus, less than 5 percent of the equipment could be expected to have additional unreliability induced through maintenance over the entire life of the system.

If we were to use the standard assumption of two to three time constants to represent the settling time for steady state, we would have to postulate a system life in excess of 400 to 600 years. I believe the initial conditions are more representative than steady state conditions. This will be true if, and only if, we can achieve or reasonably approach our Minuteman reliability goals.

William L. Still
Major, USAF
Gardena, Calif.

Charts revolve in days;
pens sweep charts in secs.

TO THE EDITOR—

Your December issue's story on General Electric's new two-pen, round-chart recorder (New Product item #316) omitted a line of copy whose absence may have conveyed some rather confusing product specifications to your readers.

Could you please bring to the at-

*Teletype Model 28 ASR—
page printer, tape reader, tape punch . . .
all in one!*



A compact data communications center

The Teletype Model 28 ASR set is a machine of many talents—time and money saving talents that are ready to go to work in your data and message communications systems.

The page printer provides facilities for sending and receiving on message paper or sprocket-fed forms. It can also be used for preparing records or as a read-out device. Platens are available to accommodate a variety of form widths, from 3½" to 9".

The punched tape equipment is unusually flexible and versatile. Facilities are provided for encoding data into tape (with or without printing on the tape) . . . transmitting from tape . . . integrating repetitive data from previously prepared tape with variable data by keyboard . . . obtaining punched tape as a by-product of communications for computer and other business machine input. There is a choice of four different punches and four different readers and, where additional tape punch facilities

are needed, a model is also available with an auxiliary tape punch.

In addition, the Model 28 ASR comes equipped with a "big plus"—the Stunt Box, a built-in programming mechanism that offers an inexpensive solution to a wide variety of remote control and switching tasks, such as automatic station selection and telemetering.

All of these facilities are available to you in a compact console measuring approximately 39" high, 36" wide and 23" deep.

Teletype Corporation manufactures this equipment for the Bell System and others who require the utmost reliability from their data communications facilities. Teletype equipment can be used with Data-Phone and other communications services.

For a free brochure on the Model 28 ASR, write to Teletype Corporation, Dept. 21-D, 5555 Touhy Avenue, Skokie, Illinois.

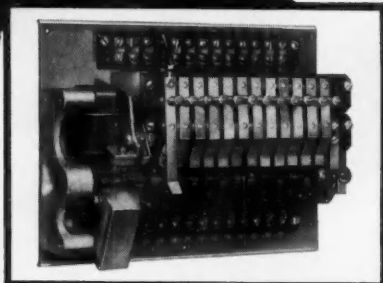
TELETYPE
CORPORATION • SUBSIDIARY OF Western Electric Company INC.

CIRCLE 15 ON READER SERVICE CARD

as simple as

$$1+2=3$$

DESIGN YOUR
NEXT MACHINE
OR PROCESS
CONTROL CIRCUIT
THIS EASY WAY



Start with

THE BULLETIN 780 STEP SWITCH
FOR STEP-BY-STEP
SEQUENCE CONTROL

1. INPUT SIGNALS

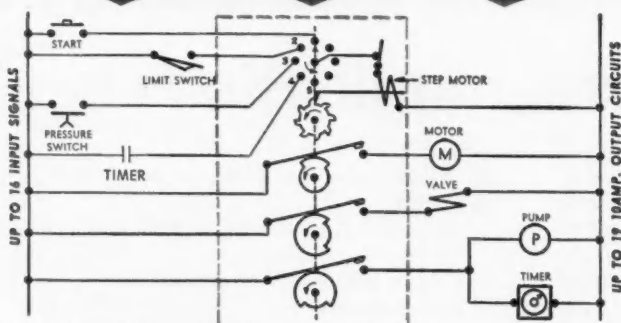
Closure of a control device, actuated upon completion of an operation, advances control to next position.

2. BULLETIN 780 STEP SWITCH

Circuits are opened or closed at each position or step according to preselected cam action.

3. PROGRAMMED SEQUENCE CONTROL

Loads are interlocked thru step switch cams without complicated relay circuitry.



Write for Bulletin 780 or call your local Representative. He's listed in Sweet's Product Design File, Section 7d/EA, or in Thomas Register.



Precision Interval Timers



Plug-in Reset Timers



Multiple Circuit Timers



Multiple Cam Timers



Predetermined Counters



Hermetically Sealed Timers

MANUFACTURERS OF THE MOST COMPLETE LINE OF INDUSTRIAL TIME-COUNT CONTROLS AVAILABLE



EAGLE SIGNAL COMPANY • Moline, Illinois
INDUSTRIAL DIVISION

DIVISION OF THE GAMEWELL COMPANY, AN E. W. BLISS COMPANY SUBSIDIARY

FEEDBACK

tention of those interested that, rather than offering pen speeds of "1, 8, 12, or 24 hrs or 7 days," GE's new recorder features pen speeds of 4, 10, and 24 sec full scale. Chart speeds are 1, 8, 12, or 24 hrs or 7 days.

Hudson S. Day
Instrument Dept., GE
West Lynn, Mass.

Twenty free enterprises neglected

TO THE EDITOR—

We have read the article "100,000 Jam INTERKAMA" (Dec., 1960, pp. 30-32) written by Mr. Derek Barlow from Dusseldorf and noticed that he completely forgot to write about the Italian group of more than 20 companies. These private concerns are defending themselves as well as they can against the new State concern.

Fabbrica Apparecchi Scientifici
Milan, Italy

Not included but not overlooked. McGraw-Hill Newsmen Gene DiRaimondo examined the surprisingly active Italian instrument and control industry in February's Industry's Pulse, p. 77. Ed.

Will road machinery adopt guidance?

TO THE EDITOR—

I would like to express my thanks for the excellent job your staff did on the article "Transistorized Circuitry for Road Machinery Control" which appears in the February issue.

We are now busy on a control for asphalt pavers which should be on the market in a few months. Not surprisingly, some quite different control problems have been encountered and (we hope) successfully solved.

John T. Bowen
Preco, Inc.
Los Angeles, Calif.

Catches error; uses article

TO THE EDITOR—

Regarding the October article "Analog Setup Plots Root Locus", Equation 10 on p. 126 should read:

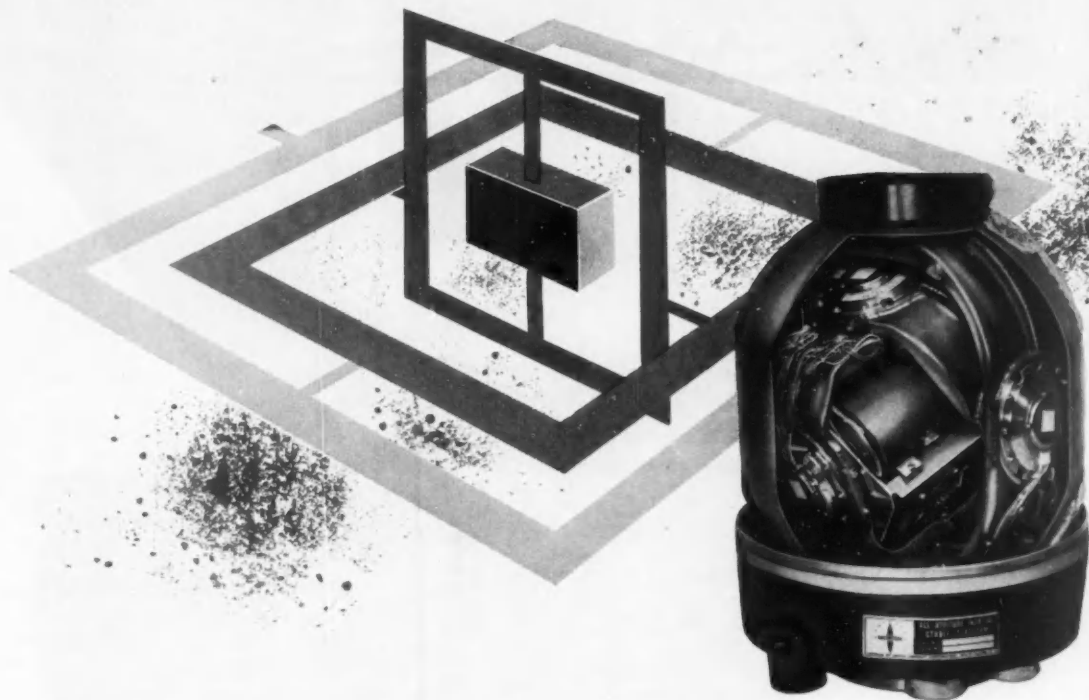
$$\frac{dr}{dt} = c_2 r^2 \frac{|u|}{u} \frac{\partial u}{\partial r} + \frac{|V|}{V} \frac{\partial v}{\partial r}$$

The partials should be taken with respect to r , not to u and v .

I found the article of great interest and have set up a successful plotter using Levine's method. Similar plots can also be made for Nyquist and Bode methods.

Robert D. Paley
The Martin Co., Orlando, Fla.

Your correction is correct, sir; glad you found the article useful. Ed.



NORDEN all-attitude, four-gimbal 20-POUND INERTIAL PLATFORM lightest, smallest now available!

An outstanding achievement in space-age electronics, this 20-pound inertial platform is another example of advanced Norden engineering and precise manufacturing. In order to develop this advanced instrument, Norden designed and built every key component... floated rate integrating gyros, accelerometers, synchros, and torquers... creating a package of exceptional accuracy and reliability.

It fulfills the need for a small size, low weight inertial platform to answer a wide range of requirements in stabilization and inertial navigation systems.

FLIGHT-TESTED AND PROVED OVER A 15-MONTH PERIOD it is now available for applications in:

- Space vehicle, aircraft, surface, and sub-surface navigation • Drone navigation systems • Attitude stabilization of aircraft, helicopters, hydrofoils • Attitude stabilization for radar antenna, radio telescopes, and space vehicle-borne optical equipment.

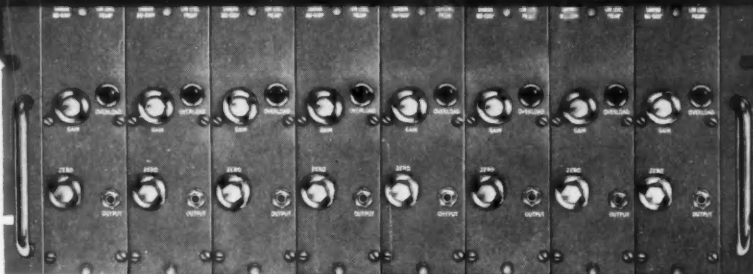
For illustrated literature including specifications, performance data and schematics, call TEmple 8-4471 or write to...



DIVISION OF UNITED AIRCRAFT CORPORATION

NORWALK, CONNECTICUT

Model 860-1500P—handles low level DC data signals in the presence of high common mode



Model 658-3400—drives high frequency optical galvanometers to 5 KC



COMPACT 7" HIGH 8-CHANNEL UNITS ARE COMPLETELY TRANSISTORIZED, HAVE FLOATING INPUT ISOLATED FROM OUTPUT

Sanborn precision amplifiers

▼ Data Preamplifier — Model 860-1500P

Designed for precise, economical amplification of signals with source impedance of zero to 10,000 ohms, such as thermocouples, strain gage bridges, etc. in presence of severe ground loop noise, and for driving digital voltmeters, scopes, tape recorders and similar devices. Each plug-in unit is only 2" x 7" x 14 1/2" deep; 64 channels with blower require only 60" of rack-panel space. Separate 868-500 Power Supply required for every 8 preamplifiers. Power consumption 2.5 watts per channel.

Noise	3 uv peak-to-peak
Gain	100 (10 mv in gives 1 v out) (Model 860-1500PA with gain of 1000 also available)
Output	± 1 v across 300 ohms, DC-70 cps; ± 1.5 v to 40 cps. Output impedance 100 ohms. (10 v across 10K available on special order.)
Linearity	± 0.1% of full scale output (2 v)
Common Mode Performance	120 db rejection at 60 cps, 160 db at DC, with 5000 ohms unbalance in source. Inphase tolerance 220VAC.
Input Impedance	Greater than 200,000 ohms
Gain Stability	± 0.1% for 24 hours
Drift	± 2 uv referred to input
Rise Time	to 99.9% less than 25 ms

▼ Optical Galvanometer Amplifier — Model 658-3400

Eight channels of amplification and common power supply. Each channel provides for sensitivity, compensation, damping and current limiting. Inputs floating and guarded, impedance 100,000 ohms on all ranges. All amplifier elements except output transistors are plug-in assemblies.

Sensitivity	± 10 mv input gives ± 400 ma output into 20 ohm load (max.). Eleven attenuator steps to X2000 in 1-2-5 ratio, smooth gain control.
Common Mode Performance	± 500 volts, max; rejection 140 db min at DC.
Gain Stability	Better than 1% to 50°C and for line voltage variation from 103-127 volts.
Frequency Response	0 to 5 KC within 3 db; can accommodate wide range of galvanometers.
Output	Output networks available for wide range of galvanometers.
Power Consumption	125 watts for 8 channels.

Your Sanborn Sales-Engineering Representative (offices throughout the U. S., Canada and overseas) will provide detailed information and application assistance. Call him or write plant in Waltham, Mass.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts

CIRCLE 18 ON READER SERVICE CARD

J. A. Haddad

sees tomorrow's systems

At IBM, Jerrier A. Haddad, General Manager of Advanced Systems Development Division, thinks the information system will become a first order control that might regulate a process, direct a company's inventory and warehousing operations, schedule manufacturing, or help run an entire business complex. He compares the relation of the information system and data processing equipment to that of a machine in production and a blueprint (a machine being a first order tool compared to a blueprint, which Haddad says is a second order tool). In the information system SABRE, which was developed by Haddad's ASD group for American Airlines, the system directly controls the sale and commitment of airplane seats in real time, in contrast to a data processing application that might analyze ticket sales. Many of the more than 11,000 electronic data processing systems now installed will be enlarged to encompass this broader information systems concept, says Haddad.

In his present position, Haddad bears the responsibility for guiding a lot of IBM's future planning. His group tackles what the company calls "risk" projects, those whose market or technical feasibility is yet to be proved. Once feasibility has been demonstrated, a product division takes over.

This kind of technical roulette suits the sharp-eyed Haddad. Although he has always had a fondness for long-range planning, his own plans had quite a different goal.

As a senior in Brooklyn Technical High School in 1939, Haddad decided that the infant field of television would be his oyster. He organized a television club and wrote articles for magazines attempting to interest outsiders in the new medium.

A summer job at Automatic Telelector Co. changed all that. He became involved in the design of a primitive data processing system, one that would telemeter data from a utility's meters, then process the information to prepare bills. His involvement became so great he delayed entering college.

Once the design was completed—Haddad received several patents for his work—he enrolled at Cornell University. While he pursued his Bachelor of Electrical Engineering degree, he continued to work part-time for Automatic Telelector. Meanwhile IBM bought AT, so after graduation Haddad, already deeply engaged in data processing, went to work at IBM's Endicott laboratory.

His first assignment was in testing equipment and designing relays. Next he was transferred to Poughkeepsie to work on circuits for the IBM 604, the



company's first calculator to rely heavily on electronic components—it had over 1,000 tubes in it.

With the success of the 604 behind him, Haddad was placed in charge of engineering for the IBM 701 computer, the first of IBM's famous 700 series, and carried the machine through design and into production before he was promoted and placed in charge of component development at Poughkeepsie.

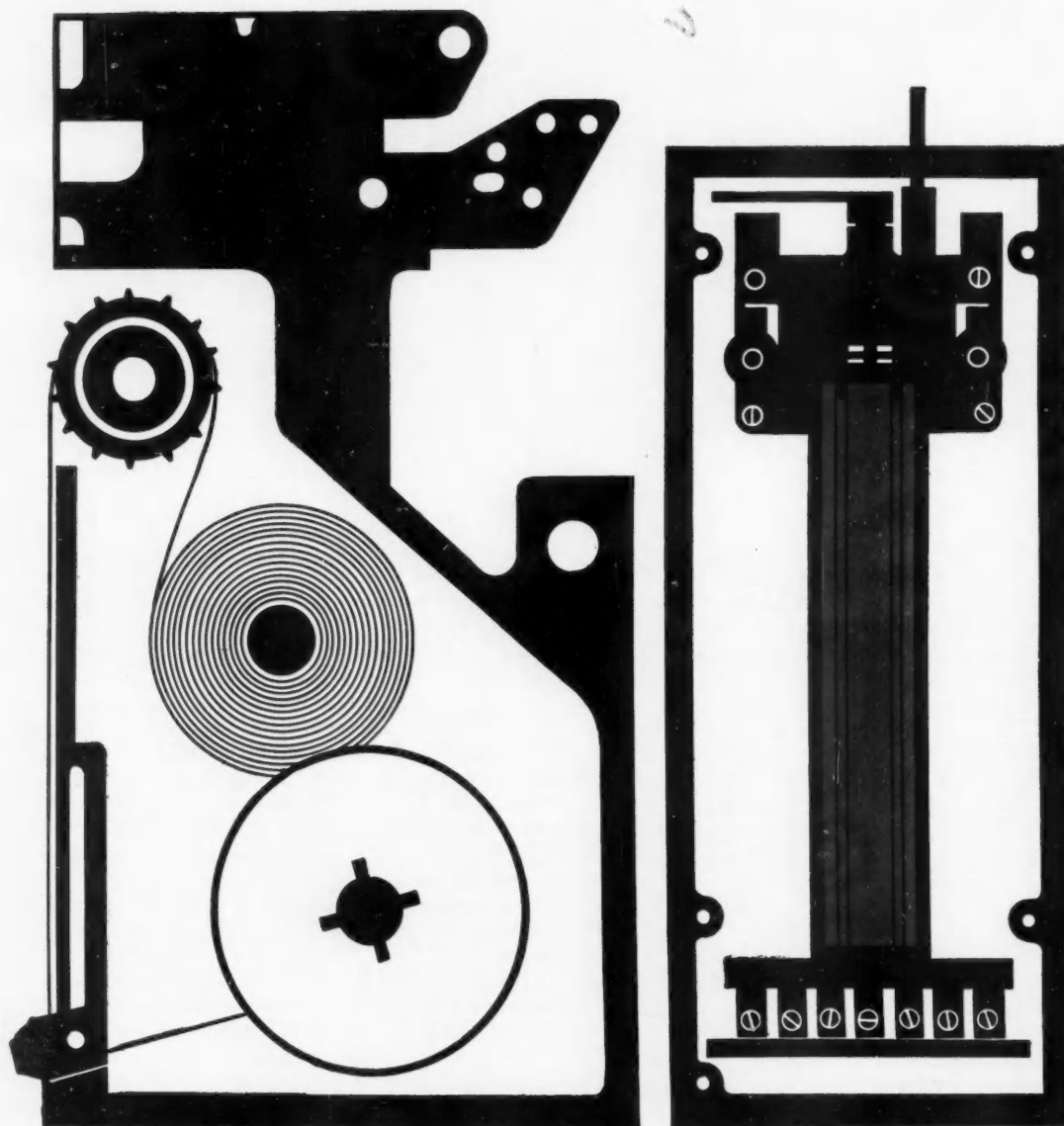
Promotions then came fast. In 1953, he became manager of the Endicott laboratory; by 1954, he was director of advanced machine development on a vice president's staff in headquarters; and in 1956, he was appointed general manager of The Special Engineering Products Div., a group set up to supply customers with IBM equipment that needed heavy modification, such as special input or output devices.

In 1959 the Special Engineering Products name and assignment was changed to Advanced Systems Development Division, and Haddad made General Manager.

Today the articulate Haddad believes four technical areas will have a profound effect on information systems. They are data communication, large capacity storage, instruments and controls, and image and speech.

Looking back over his 20 years in data processing, during which he has earned 12 patents, Haddad sometimes wonders what would have happened if he had gone into television. But his daydreaming is always cut short by the need to consider some new possibility for tomorrow's computer technology. "After all," he says, "information systems are now at the same place that punched-card procedures were when I got into this business."

ALL-NEW *Electronik 17* POTENTIOMETERS



NO SLIDEWIRE, NO SLIDEWIRE PROBLEMS. The unique **STRANDUCER** rebalancing element, an innovation in potentiometer design, replaces the conventional slidewire. It works on the proven strain gage principle and consists of four looped wire strands which form the resistance legs of a Wheatstone bridge. Both **STRANDUCER** and pen carriage are linked to the potentiometer balancing motor. A change in electrical input causes the balancing motor to change the tension—and electrical resistance—of the **STRANDUCER**. This in turn causes the balancing motor to rebalance the bridge, at the same time repositioning the instrument pen or pointer. The **STRANDUCER** is unaffected by corrosive atmospheres and has no contactors. It has unusually long life and infinite resolution and is unaffected when the instrument is subjected to ambient temperatures up to 130° F.



HAVE NO SLIDEWIRE, NO SLIDEWIRE PROBLEMS

Revolutionary STRANDUCER rebalancing element replaces slidewire...has unusually long life, infinite resolution*

Here is a totally new kind of potentiometer with a totally new kind of measuring system. The *STRANDUCER* rebalancing element replaces the slidewire, and sets a new high standard for potentiometer performance. The new *ElectroniK 17* potentiometers have a calibrated accuracy of $\pm 0.25\%$.

In addition, modular construction makes *ElectroniK 17* instruments easiest of all potentiometers to operate, convert and maintain. Complete interchangeability of components cuts service downtime and minimizes spare parts stocking requirements for these advanced potentiometers.

You can get *ElectroniK 17* instruments as strip or circular chart recorders or circular

scale indicators. You can get electric contact control with up to 8 contacts. All control units are of convenient plug-in type.

ElectroniK 17 is one of the great advances in potentiometry, and you should have all the eye-opening facts about this new class of instruments. For complete details, call your nearby Honeywell field engineer, or write MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.—In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

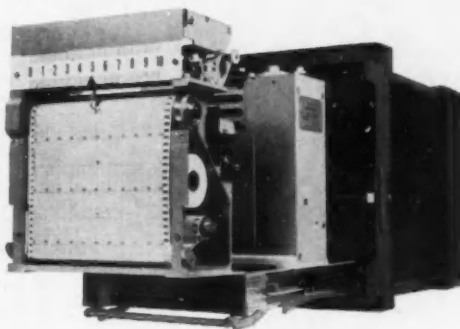
Honeywell



First in Control

SINCE 1885

True modular construction saves you time, trouble, money. Three basic modules—case, display and drive—make up the *ElectroniK 17*. The case fits standard 19-inch relay racks. You can remove the door easily and without tools when converting from strip chart to circular chart or circular scale operation. You can pull out the chassis to the service position without tools, and without interrupting operation, or remove it completely. You can change chart speeds to $\frac{1}{2}$ or 2 times basic speed (Standard chart speeds: 1, 2, 6, 10, or 60 inches per hour) by replacing quick-change drive gears. You change range and actuation simply by changing cards. Zener diode constant current supply eliminates battery problems. Up to 8 plug-in contact control modules provide for a wide variety of control possibilities.



HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

APRIL 1961

CIRCLE 21 ON READER SERVICE CARD

21

NEW BELL LABORATORIES RESEARCH FORESHADOWS COMMUNICATIONS AT OPTICAL FREQUENCIES

A revolutionary new device, the continuously operating Optical Gas Maser, now under investigation at Bell Telephone Laboratories, foreshadows a whole new medium for communications: light.

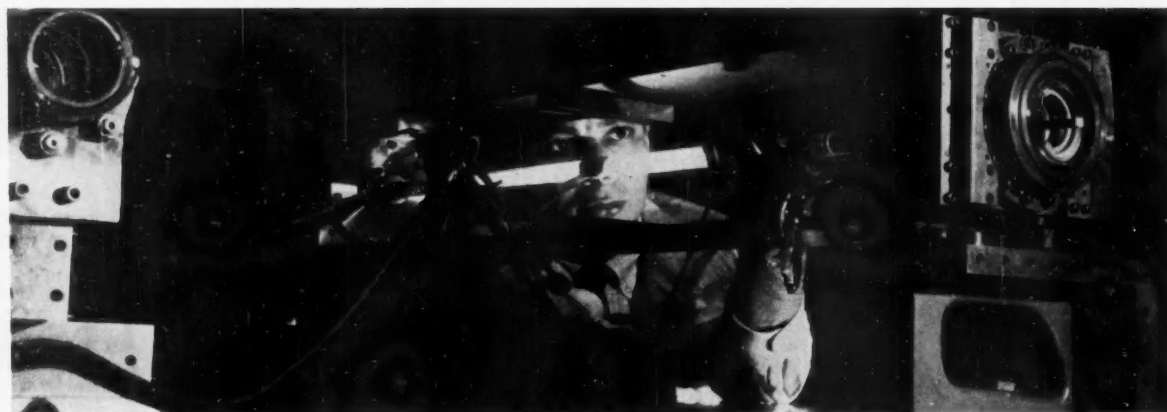
Light waves vibrate at frequencies tens of millions of times higher than broadcast radio waves. Because of these high frequencies, a beam of light has exciting potentialities for handling enormous amounts of information.

Now for the first time, Bell Laboratories' new Optical Gas Maser continuously generates light

waves that are "coherent." That is, the light waves move in phase as seen looking across the beam.

With further research, it is expected that such beams can be made to carry large amounts of information. The beams can be transmitted through long pipes. They can be projected very precisely through space, and might be used for communications between space vehicles.

Research with coherent light is another example of how Bell Laboratories prepares ahead for communications needs.



The Optical Gas Maser (above) was first demonstrated at Bell Telephone Laboratories. Heart of unit is a 40-inch tube containing helium and neon. Interaction between gas atoms produces a continuous, coherent beam of infrared light that may one day be used in communications.



BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

Newsbreaks In Control

C&E
APRIL 1961

J & L Drops Own Numerical Control

Springfield, Vt.—Machine tool builder Jones and Lamson will no longer make its own numerical control system. The company says it, as a machine builder, cannot keep up with electronic suppliers who specialize in control. In the future J & L will buy numerical control systems from outside suppliers for those customers who order such control.

Automatic Doffer for Textile Industry

Spartansburg, S. C.—A semiautomatic doffer, developed by Deering-Milliken, promises to radically change the textile spinning business. Manual doffing—removing a bobbin full of thread from a spinning frame and replacing it with an empty one—has been a troublesome part of spinning, takes 12 minutes even when done by a skilled workman, and “doffers” are scarce. Semiautomatic doffer will simultaneously “doff” the 288 bobbins on a mill in two minutes.

Punch Tape Winds Coils

Chicago—A punch tape controlled coil winder puts coils into production in 25 percent of the time it formerly required. Previously at Motorola's military electronics engineering plant, coils were wound on machines programmed by cams. But a cam could not be changed from winding machine to machine once it has been perfected, a restriction eliminated by punch tape control.

Data System Makes Fuel Terminal Self Service

Phoenix—An automatic transaction recording system, installed at El Paso Natural Gas Products Company's bulk fuel terminal here, makes for self service loading. A credit customer receives a key and a punched card. The key opens a card reader that accepts the punched card with customer identification and product to be purchased encoded on it. After the system verifies the information on the card, it activates the proper product pump; meanwhile amount, type of product, and customer identification are put into punched card format at the terminal's center. Supplier of the system is Electro-Logic Corp., of Venice, Calif.

Britain To Build Defense Computer

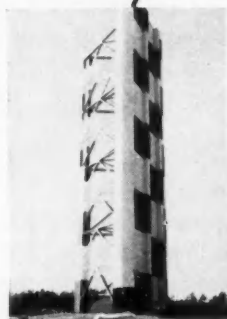
London—England's Royal Navy is developing an information system to track and classify targets automatically, store and display the information, then calculate and recommend a course of action. Civil Lord of the Admiralty told Parliament that such a system was needed because it was no longer possible for men to assimilate all the information that goes into making a defense decision such as which particular weapon should face which particular threat. The Royal Navy hopes the system—called ADA for Action Data Automation—will be flexible enough to reprogram as weapons and weapon policy change.



AGACS



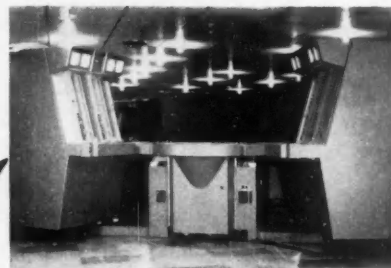
INPUT



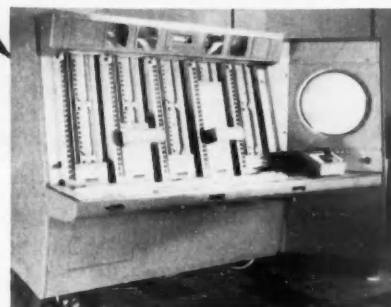
RADAR



COMPUTER



APPROACH CONTROL



ENROUTE CONTROL

DATA PROCESSING CENTRAL

SPECIAL NEWS REPORT: New Ideas in Air Traffic Control

Two events likely to influence air traffic control sharply in the United States unfolded last month: at Atlantic City, Federal Aviation Agency experimenters watched a giant altitude radar track a Piper Cub airplane for the first time. Meanwhile in Washington, Civil Aeronautics Board Examiners were completing their investigation of the mid-air collision that killed 133 people over Brooklyn in December.

The two events are related. They point out a serious shortcoming in FAA's original program to modernize the Air Traffic Control system. There is a desperate need for a position-data-acquisition system. The radar, said an FAA spokesman, is the first piece of equipment that looks capable of

preventing collisions like the Brooklyn tragedy. The CAB investigation, and attendant publicity, has pressured FAA to speed up its search for a data acquisition device such as 3-D radar.

• **Nine jobs to do**—At its Washington Headquarters and at its Atlantic City experimental facility FAA has been pursuing its program to ease the air traffic jam (see box). Implementation of Phase II of its program—application of existing technology to air traffic control—has now been divided into nine functions:

- ▶ Flight plan acceptance, processing, and distribution.
- ▶ Automatic updating of flight strips.
- ▶ Time and altitude conflict prediction, resolution, and display.

- ▶ Bright radar display.

- ▶ Flow control.

- ▶ Radar track-while-scan with tracker-driven alphanumeric data.

- ▶ Profiles and sequencing for transition and terminal control.

- ▶ Radar beacon interrogation.

- ▶ Scramble corridor and conflict prediction, resolution and display.

According to present FAA schedules, the first center incorporating mechanization of all nine functions will not be operational until 1964. Most important piece of equipment in this program is a special purpose digital computer developed by Librascope Div. of General Precision to end manual air traffic paperwork. FAA has also sponsored the development of special peripheral equipment to

work with the computer.

FAA computer specialists are now testing the Librascope computers in Atlantic City. To obtain operational experience, the Agency inaugurated what it calls "phase one-and-a-half", the installation of the Librascope computer in the Boston ARTCC at the end of this year. In Boston, the computer will perform only three of FAA's nine functions: flight plan acceptance,

processing and distribution; automatic updating of flight strips; and bright radar display.

The Brooklyn tragedy and more intimate understanding of what Phase II equipment will do have convinced FAA top scientists that the program needs at least two more functions: the data acquisition system previously mentioned to assure that a pilot maintains the course and altitude to which

he is assigned, and an all-weather automatic landing system. Although the computer helps in the sequencing of aircraft at a busy terminal—and can even suggest to the controller a path stretching pattern for the aircraft—the landing operation takes too long in bad weather, this is a bottleneck.

The airlines want an all-weather landing system too. Last year, U. S. airlines lost \$23 million as a result of

TRAFFIC JAM IN THE SKIES

Over 200,000 airplane flights are completed in the United States every day. More than 9,000 airplanes are in the air at any instant. Because most of these are flying between major cities, they funnel into a small number of narrow corridors called airways. And at the end of a typical working day, the rush of air travelers going home swells the total number of flights and creates a mammoth traffic jam at airports in cities from New York to Los Angeles and Atlanta to Chicago.

How to break these traffic bottlenecks with new control equipment has become the number one job of the Federal Aviation Agency's Bureau of Research and Development. In Washington, BRD planners set concepts for over-all system operation; in Atlantic City at BRD's National Aviation Facilities Experimental Center, testers evaluate the hardware produced by industrial contractors to fulfill the system concepts.

The FAA is following a broad plan first adopted in 1956 by the Curtis report, a document prepared by a committee which President Eisenhower convened to investigate air traffic control after the Grand Canyon air collision. The plan has three phases:

- Phase I—in-service improvement of the current air traffic control system.

- Phase II—application of existing technology (as of 1957) to air traffic control; equipment to be operational by 1963 and to handle traffic until 1975.

- Phase III—long range research and development.

To follow this proposal, FAA has committed itself to mechanize the present air traffic control system, an approach that has evoked criticism because some people feel the system has evolved like Topsy, patched up on a hand-to-mouth basis (see "Grumbles over Air Traffic Control", CIE, Jan. 1959, pp. 22-26).

On a day on which most of the U. S. enjoys clear weather, less than ten percent of the aircraft flying will be under FAA traffic control; the rest will fly VFR—visual flight rules—so that the pilot assumes responsibility for avoiding collision with another plane. Even under such ideal conditions the U. S.'s old manual traffic control system has creaked with overload. During peak periods of the day or when bad weather forces an end to VFR flying, the traffic control centers are swamped. The result: delays in takeoff and landing that amount to as much as an hour at such busy airports as Washington or New York's La Guardia and Idlewild.

While a plane is supervised by the FAA's new air traffic control system, it will pass through three different phases of control: terminal, transition, and enroute. When a plane is 20 miles from an airport, either preparing to land or just after takeoff, it is directed by a terminal controller (who is also called an approach controller if he handles primarily incoming planes and a departure controller if he is sequencing takeoffs). Through a distance of 20 miles to 100 miles from the airport a transition controller directs traffic. And from 100 miles from takeoff to 100 miles from the destination, the plane is responsible to an enroute controller for traffic direction.

Although statisticians say that the chances of mid-air collision are remote, no zone of control has been without a well publicized accident. In 1956 TWA flight 2 collided with United Flight 718 while flying in the portion of the skies directed by enroute control. A National Guard jet knocked a Capitol Airlines flight out of the skies in a transition zone outside Baltimore. And the worst accident in aviation history—TWA flight 266 colliding with United's flight 826 over Brooklyn—happened in a terminal zone.

To appreciate what FAA is doing and why, you have to understand how air traffic is controlled. Here is a brief account of how the air traffic control system would operate today while Anonymous Airlines Flight 10 flew from New York to Washington, D. C. flying IFR—Instrument Flight Rules.

First step occurs in New York when AA 10's pilot prepares a flight plan, selecting a route. He chooses to fly at 14,000 feet and his flight plan reads: take off from Idlewild; to Woolf Intersection; Victor 16 airway to Nottingham; direct to Andrews low frequency range; to Washington. AA files this plan with the New York Air Route Traffic Control Center (ARTCC) at least 30 minutes before scheduled takeoff time.

On this trip AA will pass through the jurisdiction of both the New York and Washington ARTCC's; and since control in a center is divided geographically into sectors, the flight will pass through the jurisdiction of Sector 7 and Sector 3 in the New York center.

When FAA receives the flight plan, a controller calculates the expected time of arrival at each of the check points indicated in the flight plan. Flight strips are prepared, one for the departure controller, one for each of the checkpoints over which AA 10 will fly and one for the approach controller. The strips contain such information as identification, type of aircraft, cruising speed, arrival time over the checkpoint, next checkpoint on trip; arrival time over that point; and complete routing.

After calculating arrival times at each checkpoint, a controller compares flight AA 10's expected arrival time with that of other planes at the same checkpoints to determine if there is any conflict—two planes expected to arrive at the same point at the same altitude within 10 minutes of each other. If conflict exists, the controller normally resolves it by changing the requested altitude of one of the planes.

After AA 10 takes off from Idlewild, the actual time of takeoff is flashed to each of the centers involved and each of the sector controllers who then update their flight strips. If AA 10 arrives at a checkpoint early or late the flight strips again have to be updated and new arrival times at future checkpoints calculated.

All this preparation of flight strips, updating, and conflict searching is bookkeeping that, along with communication with airplanes, takes up 94 percent of a controller's time. The preparation of flight strips alone is a mammoth job: the New York ARTCC prepares 12,000 flight strips every day, almost five million a year.

DEPENDABLE SWITCHING



**of contact loads
to 25 amps . . .**

"Diamond H" Series W Relays—The simple, functional construction of this high-quality general-purpose relay assures long-time dependable switching. For a broad range of applications, specifying "Diamond H" Series W Relays makes good sense. Here are some reasons:

Reliable—Mechanical life in excess of 10,000,000 cycles.

Versatile—a-c or d-c units available with choice of eight different combinations.

Compact—Measures $1\frac{1}{2}$ x $1\frac{1}{2}$ x $1\frac{7}{8}$ inches—weighs less than 10 oz.

High Contact Rating—Conservatively rated up to 25 amps, 240 v a-c or 28 v d-c.

Easy to mount—Plug-in design. Panel or side mounts also available.

Underwriters Laboratory Approval—
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Cost-saving—Low in initial cost, the Series W is easy to install, saves space, and is easy to service.

Send for complete facts—in new 8-page Series W Relay Guide.



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New Ideas in Air Traffic Control *cont.*

diverted equipment, and hotel and food bills for stranded passengers. The figure doesn't include revenue lost because tickets were not used or because passengers traveled by alternate means of transportation during the bad weather.

• **Changing computer view**—The computer now at Atlantic City is somewhat different from the machine FAA envisioned in 1957. For one thing, the agency thought they might be able to buy an off-the-shelf design, modify it slightly for air traffic control. For another, it was interested in two computers: one for enroute and the other for terminal control.

FAA has settled on one machine for both zones of control, a specially designed special purpose computer. Since 1958, a few air traffic centers have been equipped with file computers to prepare flight strips automatically. Table 1 compares the performance of the FAA's special purpose machine with the File computer and the Air Force's Sage computer in air traffic operations.

The special purpose machine will operate at about 75 percent of capacity. At this rate, in every hour a data processing central should be able to receive 440 flight plans, compute and print 1,600 flight strips, take in 2,000 keyboard entries of changes, and perform 1,770 conflict searches.

The machine that will go into Boston will differ somewhat from the computer now at Atlantic City. Programming and program running times have turned out to be stumbling

blocks. So far, the FAA has programmed the computer only to calculate arrival times, and to print out and update flight strips. Conflict prediction remains to be programmed.

To simplify programming, FAA has ordered the addition of index registers in future computers.

Preliminary tests have shown that file memory access time is considerable—more than half computer operation time is transferring data to and from the memory drums. To reduce this, FAA has asked the manufacturer to double the core memory storage—from 4,000 words to 8,000 words—and to improve circuitry so that access time is cut from 24 microsec. to six microsec.

• **More changes ahead**—Before the computer completes its Atlantic City evaluation, additional changes are likely to be made. For example, FAA is studying the adoption of a trunk line system for handling computer outputs. At present, each controller's console is connected to the computer by a separate electric line. A message for a console is directed by the computer to the particular line serving it.

In a trunk line system, the computer will code messages for a console, send it out over a single output line; a sampling device will direct it to the proper console.

The big advantage of the trunk line is to reduce the amount of buffer storage in each individual console. At present, each console has its own buffering to hold a message until it is completely received. If the trunk

Table I
Computer Comparison in Air Traffic Control

	File Computer	FAA Computer	Sage Computer
Time (microsec.)			
Addition time.....	1,900	48-58	12
Multiplication time.....	42,300	102-678	12-180
Division time.....	33,600	152-656	12-180
Shift (Right or Left) time.....	460	56	6-36
Compare time.....	9,000	48	12
Memory Access.....	2,500	24*	6
Instructions performed per sec.			
Multiply.....	61	2,000	10,000
Divide.....	47	2,000	10,000
Add.....	530	35,000	85,000
Clock Rate.....	168 kc	489 kc	
Memory (bits)			
Core.....	none	448,000	262,144
Drum.....	9,000,000	28,672,000	4,900,000

* New models will have a 6 microsec access time.

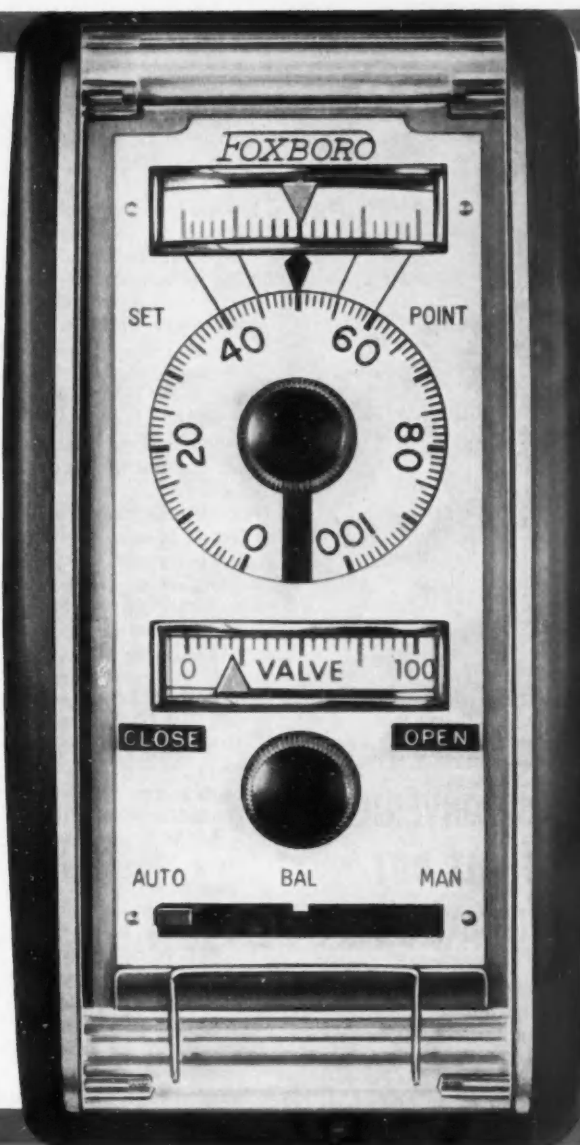
Measurement
deviation...

plus
indication...

plus
valve position...

you get them all
with this
**Foxboro electronic
control station**

Shown here actual size →



One 3" x 6" panel station containing all control and supervisory functions — that's the Foxboro Electronic Consotrol* Controller. All d-c input — all d-c output — all solid state. Operates completely independent from recording.

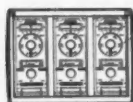
And look at these other features:

- measurement and deviation indicator gives continuous indication of process measurement as well as showing the deviation from set point.
- calibrated set point dial, with $4\frac{3}{4}$ " scale, used with

- deviation indicator for readability of $\frac{1}{2}\%$ full scale.
- valve position indicator for continuous, horizontal-scale indication of valve opening.
- simple auto-manual transfer switch for smooth, bumpless transfer.

Foxboro electronic Consotrol control stations are available for cascade, ratio and auto-selector systems. Ask your Foxboro Field Engineer about them — or write for Bulletin 21-10. The Foxboro Company, 854 Neponset Avenue, Foxboro, Massachusetts.

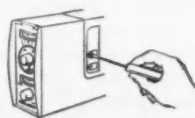
*Reg. U. S. Pat. Off.



Standard 3" x 6" housing holds 3 control stations, or 1 station with a companion recorder.

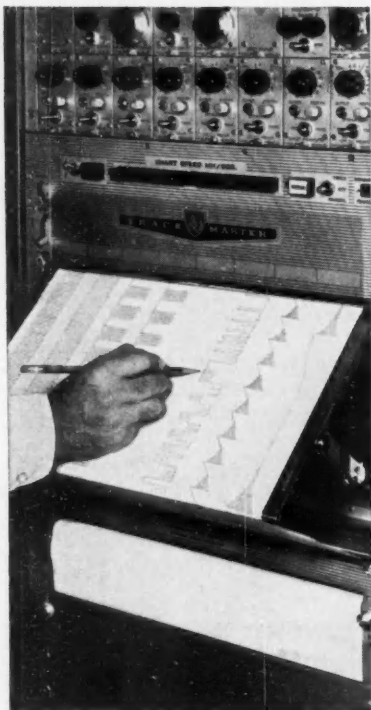


Controller and recorder each slide out from panel for easy servicing.



Proportional — reset — derivative; all adjusted from the front.

FOXBORO
REG. U. S. PAT. OFF.



ONLY AO TRACEMASTER OFFERS CONVENIENCE OF TILT-OUT WRITING TABLE!

Only the AO Tracemaster offers this convenient, tilt-out writing table. Smooth, positive linkage lets you tilt the exposed section of the chart out to a just-right 50° angle. An automatic braking device on the paper take-up mechanism maintains taut, wrinkle-free chart surface across the table.

You can tilt the table and measure the record or write on the chart while the Tracemaster is recording... you don't interrupt the trace or interfere with the amplitude of the record in any way. When you're finished, simply snap the table back flush with the front of the cabinet... paper take-up mechanism automatically rolls up loose chart paper.

This extra convenience is another of the plus benefits offered by the AO Tracemaster... the World's newest and finest 8-channel direct writing recorder. Get the complete Tracemaster story in detail. Colorful, 32 page Brochure is yours for the asking. Write for your copy today!

American Optical Company

Instrument Division • Buffalo 15, New York

New Ideas in Air Traffic Control *cont.*

line system is installed, all messages will be held in computer buffering, resulting in simplification and reduction of cost of the consoles.

• **Data acquisition**—When the Phase II air traffic control system goes operational in 1964, all the inputs will be made manually. True, FAA will have devices like Fliden, a special purpose computer that receives a flight plan, converts it to computer format, displays it to an operator, then transmits an entire plan to the computer, but even Fliden has a mechanically operated keyboard. Updating will stem from position reports made by the captain of the aircraft being controlled.

Automatic data acquisition is coming—it is now only a matter of time. FAA already is well along testing AGACS (Air-Ground Automatic Communication System), a digital data link to carry routine fix messages. Using AGACS, an aircraft will carry special equipment capable of measuring altitude, heading, and speed; the pilot will dial in checkpoint identification. When the plane flies over the checkpoint, the pilot will push a button to transmit a message to ground at the rate of 750 bits per sec.

AGACS contains 32 discrete messages. Normally it operates on a "don't call us, we'll call you" basis. It can sample messages from 250 aircraft a minute.

Still to be resolved is the question of how to display AGACS information to the pilot. One suggested approach would display an electronic digital readout in the cockpit; another would produce hard copy in the form of printed Teletype tape for the pilot.

• **Three-D radar**—Although all the military services have experimented with three-dimensional radar, FAA maintains that none of the equipment so far demonstrated has sufficient resolution for air traffic control. ATC radar must be able to differentiate aircraft flying at altitudes 1,000 feet apart.

FAA now thinks it has the answer in a new high resolution system developed by the Maxson Corp. Here is how it works. A conventional S-band radar sends out a signal whose return to the transmitting antenna provides conventional position information. A second antenna (called the AHSR-1), which towers 16 stories high, 168 feet into the air, also receives the rebound signal, compares it with the initial transmission carried by wire to a special purpose computer to measure altitude.

Although FAA has not yet started

its evaluation of the Maxson system, an FAA spokesman predicts the agency will install the system at five or six installations.

This three-D radar almost defies the imagination. For surveillance over 360 degrees horizontally, the antenna is made up of three legs, each 16 stories tall and twenty feet wide, arranged to form a giant triangle. In each leg there are two walls of wave guides, each wall made up of 10 miles of carefully machined aluminum guide, that, when assembled, weighs 80 tons.

The Maxson 3-D radar is likely to cost FAA at least \$1 million per installation. But any system of automatic data acquisition is going to be expensive.

• **Radar backup**—Hans Giesecke, FAA's Chief Scientist at Atlantic City, feels certain another kind of data acquisition will eventually be needed to back up radar data. It is impossible, says Giesecke, for radar to be 100 percent effective all the time. Radar can handle about 80 percent of the load, so FAA is currently considering several other methods of automatic tracking.

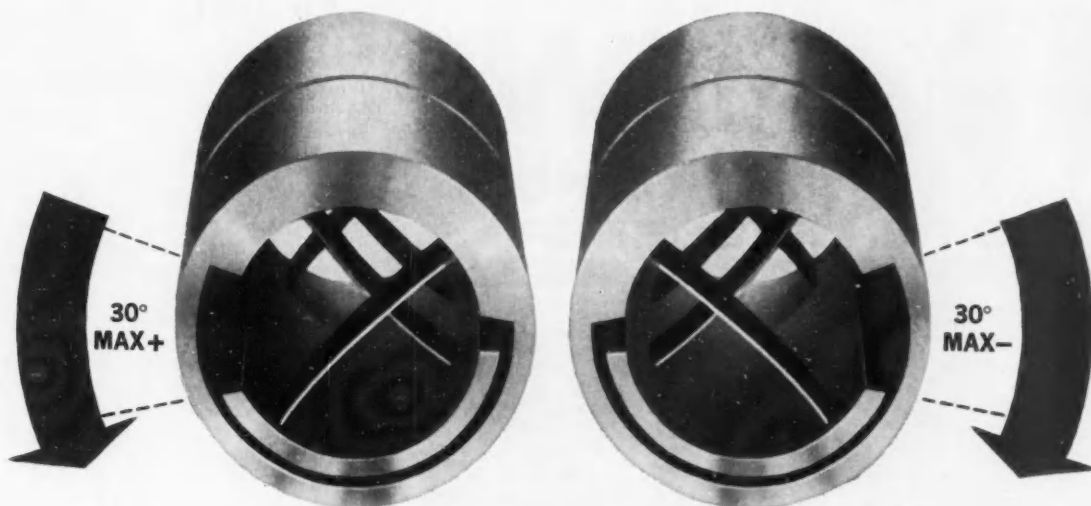
A big question to be answered is, can the AGACS automatic communication supply this backup; or will tracking require a system that relies on even more equipment in the aircraft?

Among the companies that have made automatic tracking proposals to FAA are Servo Corp., Thompson Ramo Wooldridge, Lockheed Electronics, IBM, and the Cubic Corp. Basically all the systems depend on tracking by several ground stations either a voice signal or a signal specially transmitted by the aircraft, and would require a nation-wide network of ground stations.

TRW, for example, would track the audio of standard VHF transmission through multiple ground stations, which would correlate the received signals to obtain a time difference; from this the aircraft position can be calculated.

IBM would put a crystal clock in an aircraft to accurately sequence the transmission of pulses. On the ground, the received pulses would be compared with those transmitted by a similar ground clock both pulses synchronized to station WWV; timing differences would supply position information.

• **Automatic landing within sight**—Within a year FAA is likely to authorize an automatic landing system for cargo craft. After testing for



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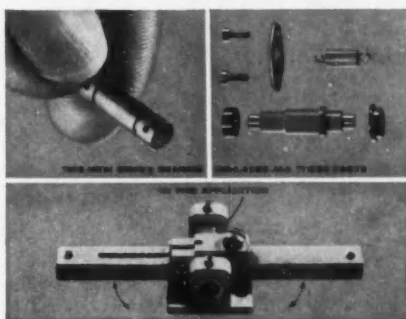
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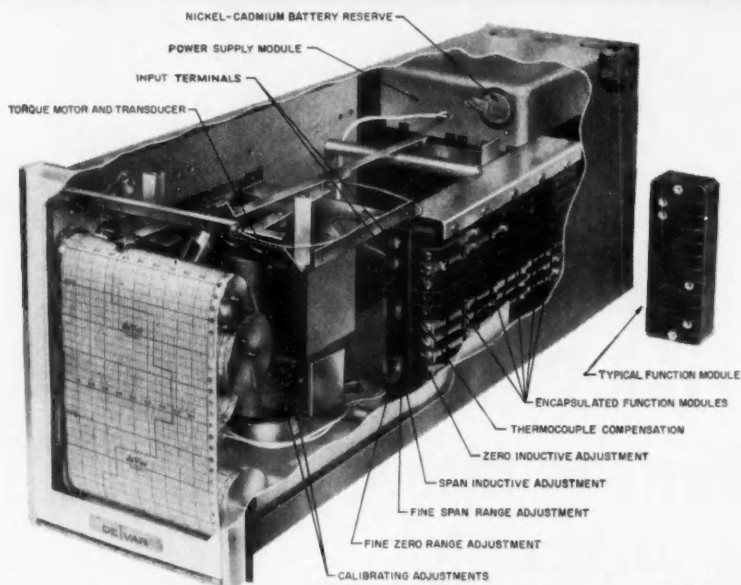




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Air Traffic Cont.

a minimum of a year in freight service, FAA will consider extending automatic landing to commercial passenger liners.

Before approving a system, FAA has to consider some nontechnical problems as well as technical ones. For example, most airline pilots are almost certain to view any automatic landing system with reluctance—at least until the equipment has been proved reliable. That is why FAA is now studying systems that might just present information to the pilot at first. After the pilots are used to the system, a coupler to the autopilot could be installed for closed-loop control and a completely automatic landing system.

At Atlantic City, FAA is testing or setting up to test six automatic landing systems. Descriptions of how four of them work are explained on page 32.

One system, the Bell Aircraft Co.'s AN/GSN-5, will probably be rejected by FAA for commercial service although the Navy has already approved and purchased seven installations. For one thing, landings with the Bell System are likely to be hard, a shock that would not disturb a Navy pilot strapped into a relatively light plane, but that could upset commercial passengers who are restrained only by a seatbelt in a heavy jet liner. In addition, the Bell System requires that a typical landing pattern for an aircraft be programmed into the computer. Since every aircraft has a distinctly different pattern, landing many different planes with the system would require reprogramming the computer for each aircraft.

The system most likely to be approved in the near future is one imported from England. Called the Blind Landing Experimental Unit (BLEU), it is currently being installed in a DC-7 aircraft that will fly to Britain to begin evaluation tests. Later the tests will be continued in Atlantic City.

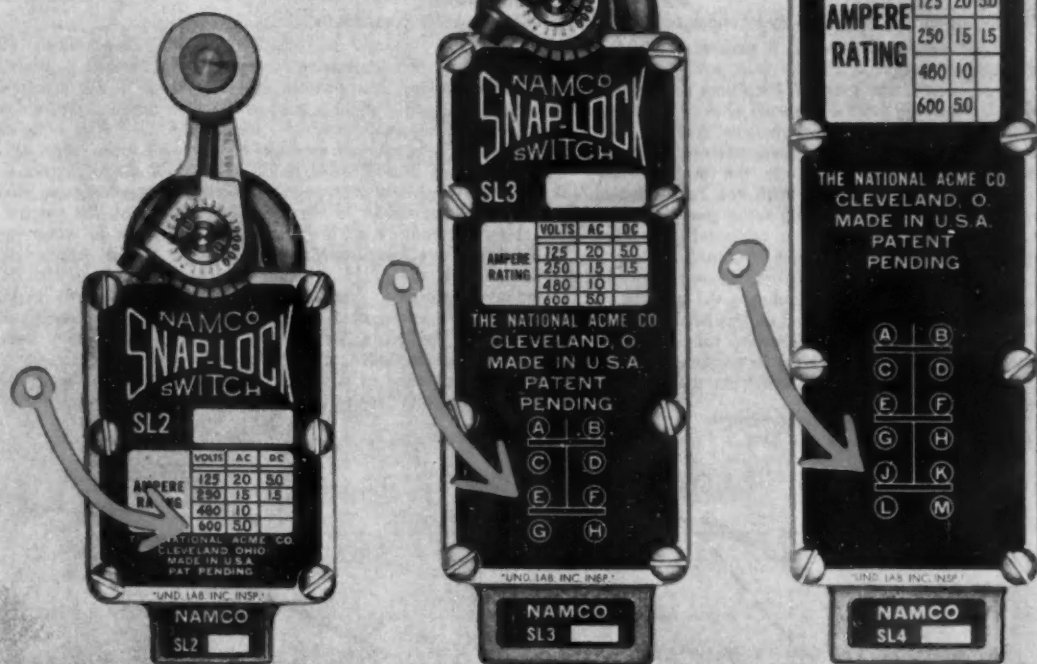
Another system that looks promising is REGAL (Range Elevation Guide for Automatic Landing). Evaluation of this system is still some time away.

Watching the bustling activity at NAFEC is a cheering sight for an air traveler concerned about air safety. But one discouraging fact emerges. When asked how far FAA was away from having operational equipment that would have prevented the collision over Brooklyn, an FAA spokesman sadly replied, "At least two years".

—Lewis H. Young

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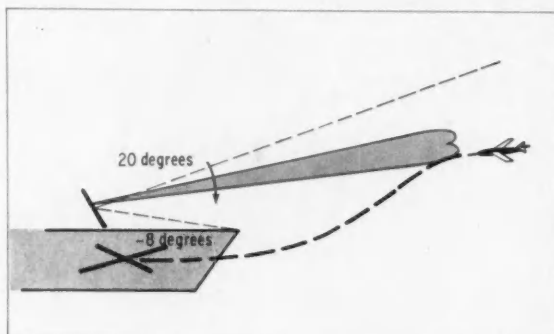
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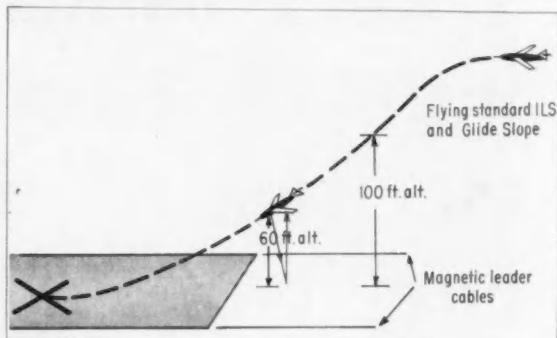
FOUR AUTOMATIC LANDING SYSTEMS



REGAL

(Range Elevation Guidance for Approach and Landing)

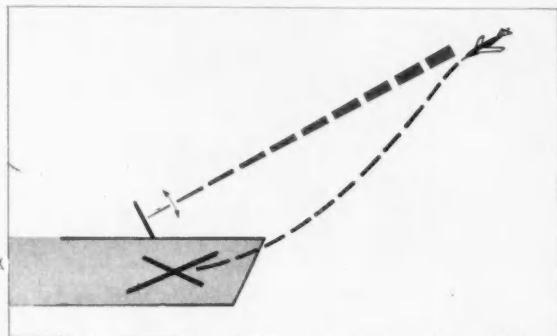
As a ground antenna sweeps downward, it generates at 9,000 Mc a notched beam composed of a pulse train which is coded depending on the position of the antenna. Each time the antenna moves 0.3 degree in its swing from 20 degrees above the surface to eight degrees below, the pulse train changes. A receiver in the aircraft determines what code has been received and from this can decide the elevation angle. Actually, the receiver measures angle at the notch of the beam. With the remainder of the beam, conventional distance measuring techniques determine range. Range and elevation data enter a computer that compares them with desired range and elevation, and the error signal operates the autopilot or advises the pilot. Conventional ILS (Instrument Landing System) is used to indicate the position of the runway centerline. Accuracy of the system has been designed to be plus or minus 0.05 degrees in elevation; range, plus or minus 50 feet at touchdown. The system is so precise it can detect a movement of six inches 1,200 feet from the antenna. Supplier: Gilfillian Bros.



BLEU System

(Blind Landing Experimental Unit)

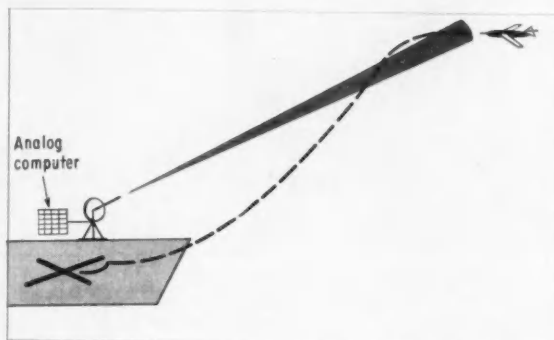
Uses standard ILS and electronic glide path to an altitude of 500 ft. British system depends on magnetic cables that run 5,000 ft in front of runway. Plane comes in on standard ILS and electronic glide slope until it reaches a point 100 feet above altitude; then it receives centerline position information from the magnetic cable. Plane coasts at constant pitch angle until altitude is 60 feet then uses altitude radar to bring plane to touchdown, sinking at a rate of 2 ft per sec. There is a question as to what effect lighting cables in the runway will have on the magnetic cables; or what to do if the runway ends close to water and the cables are laid in water. FAA believes that a modified ILS director and the radar altimeter may be sufficient, so that the magnetic cables can be eliminated. The British, on the other hand, feel that ILS information is not accurate enough because of distortion of the beam, particularly when the aircraft is under 100 ft. altitude. In England, the system, with magnetic cables, has been installed at a military base and performed well with bomber aircraft. Supplier: Royal Aircraft Establishment at Farnborough.



EGAL

(Elevation Guidance for Approach and Landing)

As antenna sweeps upward and downward, 16,000 Mc variable pulse is transmitted in a pencil beam. During an upward scan, spacing of pulses varies from 16 to 96 microsec. changing at the rate of four microsec. per degree. On the aircraft, a receiver identifies the timing of the pulses and determines the angle of elevation of the aircraft. This system is designed for an error of plus or minus 0.01 degree in the flare region and 0.05 degree near touchdown. In this modification, EGAL supplies information to the pilot. For automatic landing application, it would be used with another system such as the Instrument Landing System (ILS).

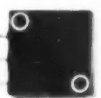


AN/GSN-5

Uses a k-band tracking radar to determine actual position of the aircraft. Actual is compared to desired position in an analog computer and error signals are beamed to the autopilot via conventional ILS beam. In a new design, control signals will be sent back via the tracking beam. Requires some sort of feeder system to bring aircraft to exact correct entrance to the system. In addition, plane must be in straight and level flight when system locks on; in case of a wave off, the system returns the plane to what it reported as straight and level flight. Plane must have a corner reflector or radar antenna will track several different parts of airplane during landing, directing the plane to jump during the approach. Supplier: Bell Aircraft Corp.

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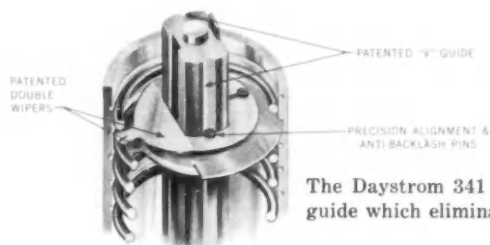
	144 MODELS	96 MODELS	144 MODELS	32 MODELS
				
SQUARETRIM® SERIES NUMBERS	300-00, 300-60, 300-61, 300-64, 300-66, 300-67	301-00, 301-60, 301-61, 301-64	303-00, 303-60, 303-61, 303-66, 303-67, 303-74	311-00, 311-60, 311-61, 311-64
RESISTANCE	10Ω — 50K	10Ω — 50K	50Ω — 150K	20K — 1MEG
POWER	1 watt (still air)	1 watt (still air)	1.5 watts (still air)	0.5 watts (still air)
SIZE	½" x ½" x 0.187"	½" x ½" x 0.255"	¾" x ¾" x 0.280"	½" x ½" x 0.187"
OPERATING TEMP.	—55 to +150°C	—55 to +150°C	—55 to +150°C	—55 to +85°C
RESOLUTION	10Ω—1.00% 1K—.32% 20Ω—.77 2K—.23 50Ω—.65 5K—.20 100Ω—.52 10K—.125 200Ω—.50 20K—.096 500Ω—.36 50K—.086	10Ω—1.00% 1K—.32% 20Ω—.77 2K—.23 50Ω—.65 5K—.20 100Ω—.52 10K—.125 200Ω—.50 20K—.096 500Ω—.36 50K—.086	50Ω—0.65% 5K—.20% 100Ω—.42 10K—.155 200Ω—.35 20K—.130 500Ω—.35 50K—.070 1000Ω—.30 100K—.062 2000Ω—.23 150K—.052 5000Ω—.18	20K 200K 50K 500K 75K 750K 100K 1MEG
Standard Resistance Tolerance	±5% (special tol. on request)	±5% (special tol. on request)	±5% (special tol. on request)	±20%
Temp. Coeff. of Resistance Wire	20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	0.2%/°C, 0° to 100°C
Temp. Coeff. of Potentiometer	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C
Stability as Voltage Divider	0.2% or 1 resolution max.	0.2% or 1 resolution max.	0.2% or 1 resolution max.	Better than 0.7%, —55 to 85°C
Load Life at Rating	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-94 (in still air)
Insulation Resistance	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)
Dielectric Strength	500V. AC, 1 min.	500V. AC, 1 min.	500V. AC, 1 min.	500V. AC, 1 min.
Useable Resistance Range	98%	98%	98%	98%
Equiv. Noise Resistance	0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	
Adjustment Ratio	45:1	45:1	45:1	45:1
Screw Turns	42	42	42	42
Rotational Life	10,000 screw rev. min.	10,000 screw rev. min.	10,000 screw rev. min.	10,000 screw rev. min.
Torque	7.5 oz/in. max.	7.5 oz/in. max.	7.5 oz/in. max.	7.5 oz/in. max.
Weight	2 grams max.	2 grams max.	7 gr. max.	2 grams max.
Temperature Cycling	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102
Vibration	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.
Shock	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202
Altitude	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.
Sand and Dust	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C
Fungus Resistance	All non-nutrient materials	All non-nutrient materials	All non-nutrient materials	All non-nutrient materials
Corrosion Resistance	Similar materials construction 100%	Similar materials construction 100%	Similar materials construction 100%	Similar materials construction 100%
Humidity*	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	
Salt Spray*	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	

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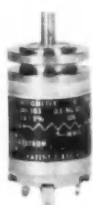
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EXAMPLE: ZERO BACKLASH



The Daystrom 341 Series rotary potentiometers contain this patented "V" guide which eliminates backlash and resultant error. U.S. Patent 2,856,493.

EXAMPLE: DOUBLE WIPERS, FINER RESOLUTION, AND ABSOLUTE CONTINUITY IN SUBMINIATURE SERIES 341 TEN-TURNS



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The Series 341 potentiometers are offered in resistance ranges from 1K to 600K, can carry 2.5 watts in still air at 40°C, and operate from -55 to 140°C. They are only 1/2" in diameter and 1" long, and meet all applicable MIL specs. The 341 can also be supplied with a patented clutch for servo installation.


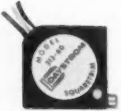
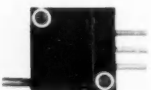



EXAMPLE: SPECIAL ADJUSTING DEVICE IN GANGABLE SERIES 319

For the first time in gangable potentiometers, you can make individual pot adjustments after ganging without disassembly. Daystrom 319's are uniquely constructed so each can be adjusted separately in 15 or 20 seconds without affecting others. Patents are pending on the special Daystrom-engineered method by which these adjustments are



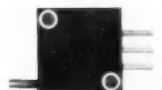


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312-00, 312-60, 312-61, 312-64	313-00, 313-60, 313-61, 313-64	315-00, 315-60, 315-61, 315-64, 315-72, 315-74	316-00, 316-60, 316-61, 316-64, 316-72, 316-73	318-00, 318-60, 318-61, 318-64	355-00, 355-60, 355-64
10 Ω —50K 1 watt (still air) ½" x ½" x 0.195" —55 to +150°C	10 Ω —50K 1.5 watts (still air) ½" x ½" x 0.187" —55 to +200°C	10 Ω —50K 1 watt (still air) ½" x ½" x 0.200" —55 to +150°C	10 Ω —50K 1 watt (still air) ½" x ½" x 0.195" —55 to +150°C	10 Ω —50K 1.5 watts (still air) ½" x ½" x 0.255" —55 to +200°C	10 Ω —50K 1 watt (still air) ½" x ½" x 0.200" —55 to +200°C
10 Ω —1.00% 1K—.32% 20 Ω —.77 2K—.23 50 Ω —.65 5K—.20 100 Ω —.52 10K—.125 200 Ω —.50 20K—.096 500 Ω —.36 50K—.086	10 Ω —1.00% 1K—.32% 20 Ω —.77 2K—.23 50 Ω —.65 5K—.20 100 Ω —.52 10K—.125 200 Ω —.50 20K—.096 500 Ω —.36 50K—.086	10 Ω —1.00% 1K—.32% 20 Ω —.77 2K—.23 50 Ω —.65 5K—.20 100 Ω —.52 10K—.125 200 Ω —.50 20K—.096 500 Ω —.36 50K—.086	10 Ω —1.00% 1K—.32% 20 Ω —.77 2K—.23 50 Ω —.65 5K—.20 100 Ω —.52 10K—.125 200 Ω —.50 20K—.096 500 Ω —.36 50K—.086	10 Ω —1.00% 1K—.32% 20 Ω —.77 2K—.23 50 Ω —.65 5K—.20 100 Ω —.52 10K—.125 200 Ω —.50 20K—.096 500 Ω —.36 50K—.086	10 Ω —1.00% 1K—.32% 20 Ω —.77 2K—.23 50 Ω —.65 5K—.20 100 Ω —.52 10K—.125 200 Ω —.50 20K—.096 500 Ω —.36 50K—.086
±5% (special tol. on request)	±5% (special tol. on request)	±5% (special tol. on request)	±5% (special tol. on request)	±5% (special tol. on request)	±5% (special tol. on request)
20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C
50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C
0.2% or 1 resolution max.	0.2% or 1 resolution max.	0.2% or 1 resolution max.	0.2% or 1 resolution max.	0.2% or 1 resolution max.	0.2% or 1 resolution max.
1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)
50 megohms min. (500V. DC)	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)
500V. AC, 1 min.	500V. AC, 1 min.	500V. AC, 1 min.	500V. AC, 1 min.	500V. AC, 1 min.	500V. AC, 1 min.
98%	98%	98%	98%	98%	98%
0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms.
45:1	45:1	45:1	45:1	45:1	45:1
42	42	42	42	42	42
10,000 screw rev. min.	10,000 screw rev. min.	10,000 screw rev. min.	10,000 screw rev. min.	10,000 screw rev. min.	10,000 screw rev.
7.5 oz/in. max.	7.5 oz/in. max.	7.5 oz/in. max.	7.5 oz/in. max.	7.5 oz/in. max.	7.5 oz/in. max.
2 grams max.	2 grams max.	2 grams max.	2 grams max.	2 grams max.	2 grams max.
Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202
Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C
Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202
Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C
Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C
All non-nutrient materials	All non-nutrient materials	All non-nutrient materials	All non-nutrient materials	All non-nutrient materials	All non-nutrient materials
Similar materials construction 100%	Similar materials construction 100%	Similar materials construction 100%	Similar materials construction 100%	Similar materials construction 100%	Similar materials construction 100%
Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C
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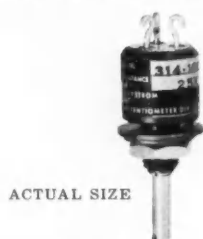
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44 MODELS	96 MODELS	144 MODELS	96 MODELS	NEW
				
356-60, 355-61, still air) 0.200" 00°C % 1K—.32% 2K—.23 5K—.20 10K—.125 20K—.096 50K—.086	356-00, 356-60, 356-61, 356-64 10Ω — 50K 1 watt (still air) ½" x ½" x 0.195" —55 to +200°C 10Ω—1.00% 1K—.32% 20Ω—.77 2K—.23 50Ω—.65 5K—.20 100Ω—.52 10K—.125 200Ω—.50 20K—.096 500Ω—.36 50K—.086	357-00, 357-60, 357-61, 357-64 10Ω — 50K 1 watt (still air) ½" x ½" x 0.200" —55 to +200°C 10Ω—1.00% 1K—.32% 20Ω—.77 2K—.23 50Ω—.65 5K—.20 100Ω—.52 10K—.125 200Ω—.50 20K—.096 500Ω—.36 50K—.086	358-00, 358-60, 358-61, 358-64 10Ω — 50K 1 watt (still air) ½" x ½" x 0.195" —55 to +200°C 10Ω—1.00% 1K—.32% 20Ω—.77 2K—.23 50Ω—.65 5K—.20 100Ω—.52 10K—.125 200Ω—.50 20K—.096 500Ω—.36 50K—.086	⅜" Squaretrim!
tol. on request)	±5% (special tol. on request)	±5% (special tol. on request)	±5% (special tol. on request)	<p>New Squaretrims only ⅜" square, less than ⅛" thick. Design advantages: smaller, lighter in weight, yet rated at one full watt in still air. Flat, compact ⅜" Squaretrim permits much greater circuit density per cubic inch, needs no mounting brackets for stacking, and the new ⅜" Squaretrim will be offered in a full line of 144 standard models. You get the famous Daystrom precision plus the famous Daystrom wide line and design latitude. Sample quantities available immediately.</p>
max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	20 ppm m/°C max. 0° to 100°C	
max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	50 ppm/°C max. 0° to 100°C	
resolution max.	0.2% or 1 resolution max.	0.2% or 1 resolution max.	0.2% or 1 resolution max.	
n. still air)	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)	1000 hrs. min. MIL-R-19A (in still air)	
min. (500V. DC)	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)	50 megohms min. (500V. DC)	
min.	500V. AC, 1 min.	500V. AC, 1 min.	500V. AC, 1 min.	
	98%	98%	98%	
ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	0.1% or 100 ohms. NA 5-710	
	45:1	45:1	45:1	
	42	42	42	
w rev. min.	10,000 screw rev. min.	10,000 screw rev. min.	10,000 screw rev. min.	
max.	7.5 oz/in. max.	7.5 oz/in. max.	7.5 oz/in. max.	
x.	2 grams max.	2 grams max.	2 grams max.	
STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	Exceeds MIL-STD-202, Meth. 102	
E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	
STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	Exceeds MIL-STD-202, Meth. 202	
E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	Exceeds MIL-E-5272C, Proc. II.	
E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	Exceeds MIL-E-5272C	
ent materials	All non-nutrient materials	All non-nutrient materials	All non-nutrient materials	
rials 100%	Similar materials construction 100%	Similar materials construction 100%	Similar materials construction 100%	
E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	Exceeds MIL-E-5272C, Proc. I.	
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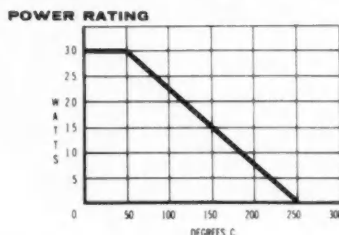
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WHAT'S NEW

Interest Shifts at Solid State Conference

The laser and magnetic logic systems grab most attention; disillusionment reported with the tunnel diode.

PHILADELPHIA—

At the annual Solid State Circuits Conference, many of those who work on the frontier of technology explode enthusiastically about new developments and are just as quick to fall into disillusion when a development fails to meet expectations. Demonstrating this excitement and depression, three themes dominated the 1961 conference: the laser (light amplification by stimulated electromagnetic radiation) as a source of coherent light is the most exciting new development in solid state physics; the tunnel diode has disillusioned those who last year thought it was the answer to every design problem; and magnetic logic units continue to intrigue designers of decision-making circuits because of outstanding reliability.

Almost every year since it has started, the Solid State Conference has spotlighted one new device. This year it was the optical maser or laser (previous stars: the tunnel diode last year; the silicon controlled rectifier two years ago). Dr. G. C. Dacy of the Bell Telephone Laboratories discussed application of the laser in space communications and data transmission and demonstrated a ruby laser.

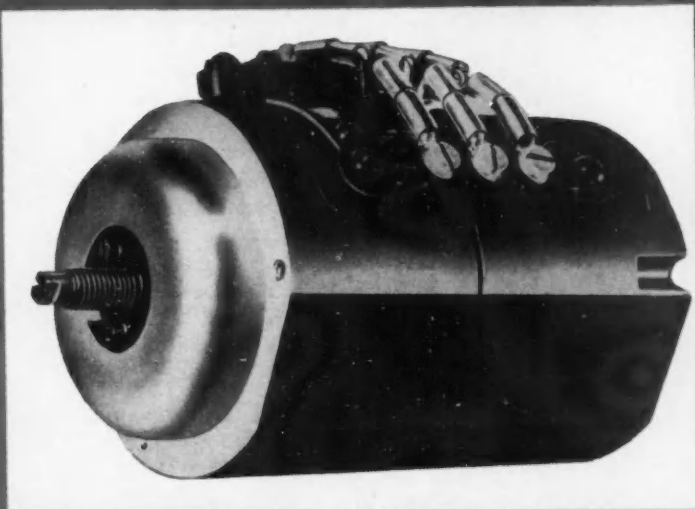
An SRO audience crowded an informal evening discussion devoted to the laser, while a similar session on the tunnel diode had as many empty seats as filled ones. At the evening session, the crowd heard that application of the laser was moving rapidly. Hughes Aircraft, for example, has developed a coherent light radar; Bell Telephone Laboratories has solved the problem of continuous operation (CtE, March '61, p. 29).

• **Limits on tunneling**—Disillusion with the tunnel diode stems mainly from the device's bilateral nature and the close tolerances required in associated components. Most circuits discussed this year employed tunnel diodes along with regular diodes or transistors.

G. B. B. Chaplin of Plessey Co., Ltd., reported how rectifier diodes can be added to tunnel diode circuits to overcome tolerance difficulties. He also described a word-organized tunnel

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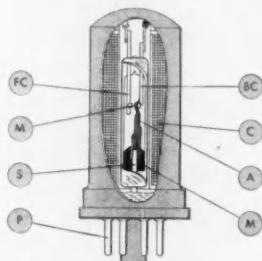
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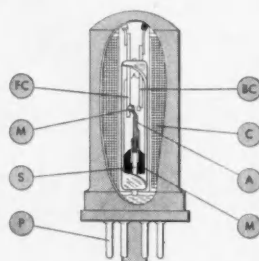


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Platinum butterfly contact at top end of swinger or armature A rests against the normally closed contacts BC completing circuit. This electrical circuit is closed through mercury M adhering to platinum swinger contact point and also mercury adhering to platinum contacts at end of normally closed contacts BC. Circuit is further connected to proper pins P to complete circuit inside enclosure with external connections.



When coil C is energized, swinger moves from the normally closed contacts BC to the normally open contacts FC. This opens the normally closed circuit and closes the electrical circuit through the normally open contacts, FC through stem S, and through proper pins P to external circuit. Mercury M from pool at bottom of switch replenishes mercury dropped after each operation from contact points so circuit is always made and broken through two mercury surfaces.

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WHAT'S NEW

diode memory with a read-reset-write-read cycle of 40 microsec for a 64-bit word. Each memory cell contains a tunnel diode, a rectifier diode, and a resistor. By choosing voltage, the rectifier orders reading or writing.

Other presentations describing application of the tunnel diode:

► J. R. Turnbull, IBM, designed a nonsynchronous computer circuit in which tunnel diodes amplify and shape the signal. Transistors drive the diodes and provide fan out.

► W. V. Harrison and R. S. Foote of Texas Instruments described clock-synchronized 100-200 Mc switching circuits with tunnel diodes. In these, the diodes are aided by emitter-follower transistors for pulse steering and impedance transformation, and pulse transformers for inversion.

► T. Yamamoto and A. Kishimoto of the Japan Defense Agency showed how a tunnel diode can be used as a parametric device in microwave computers. The diode receives energy while in the positive resistance region and delivers while it has negative resistance.

► Professor E. Goto, University of Tokyo, has designed tunnel diode logic circuits with transformer coupling to facilitate negation and supply impedance matching.

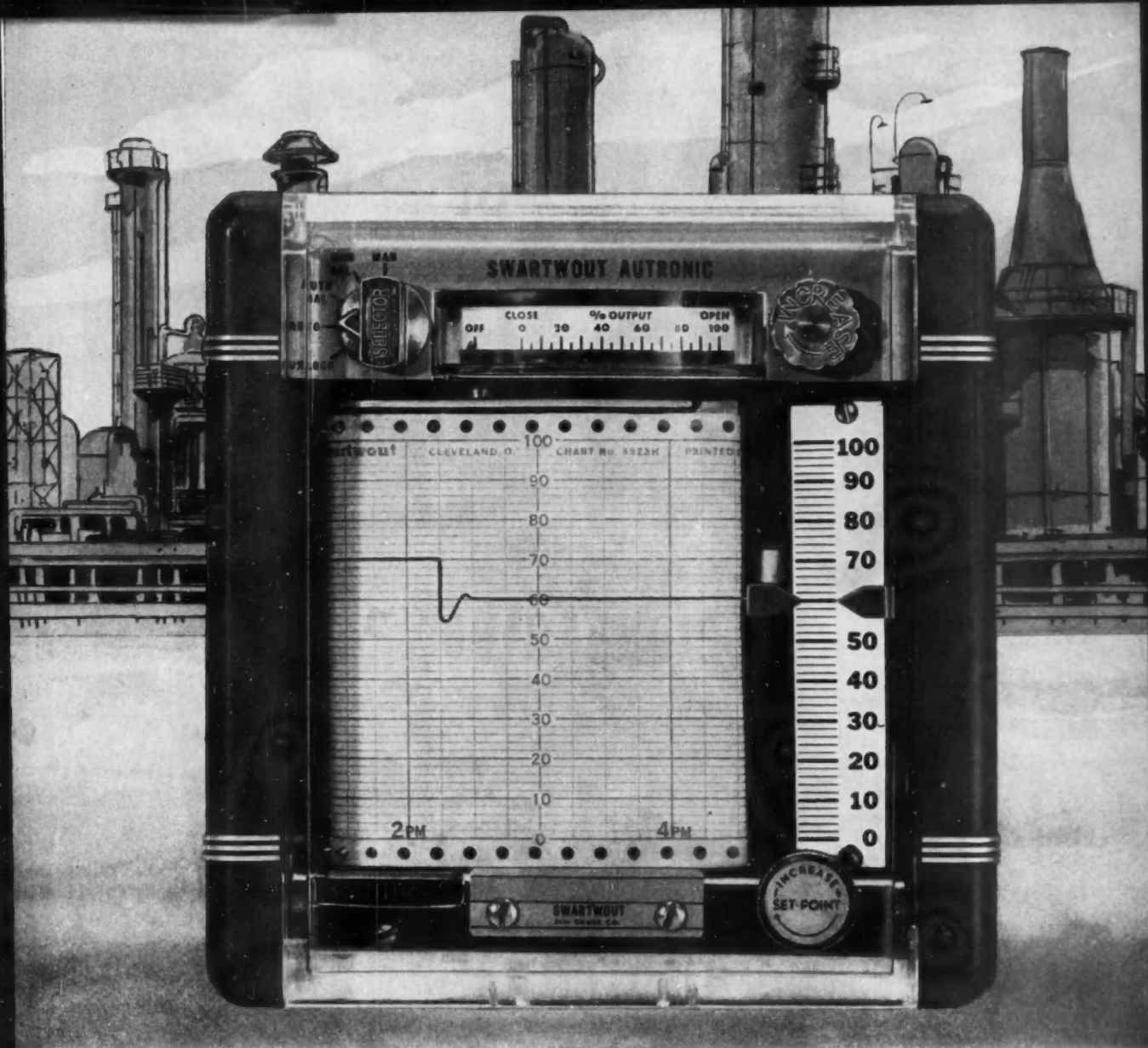
The prospects for new and faster tunnel diodes made of gallium arsenide have suffered a setback. Such devices produced to date have a lifetime of only a few months. J. Tie-mann of General Electric said there are two phenomena at work, neither of which is now understood.

• **New logic devices**—Something new discussed was the neuristor, a class of structure that can propagate a signal with no attenuation. H. D. Crane, Stanford Research Institute, has designed many neuristors on paper, is now ready to build some.

Another unusual logic system described is optoelectronic, composed of two materials: one electroluminescent and the other photoconductive. T. E. Bray of GE, who described the units, pointed out that although they are potentially inexpensive, their speed is limited by a slow change of state, of the order of 0.2 sec.

Other presentations at the conference show attendees are shifting their interest from the theoretical aspects of solid state physics to hardware. There was even much interest shown in microminiaturization techniques and how to position components physically in hardware such as computers.

—M. P. Southworth



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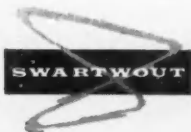
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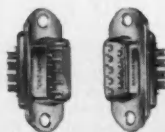
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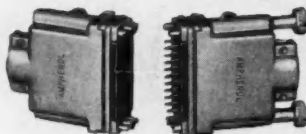


PIONEERING

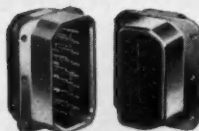
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Britain's Pattern Recognizer

A London professor is building an analog pattern recognition device that may be flexible enough to identify human faces.

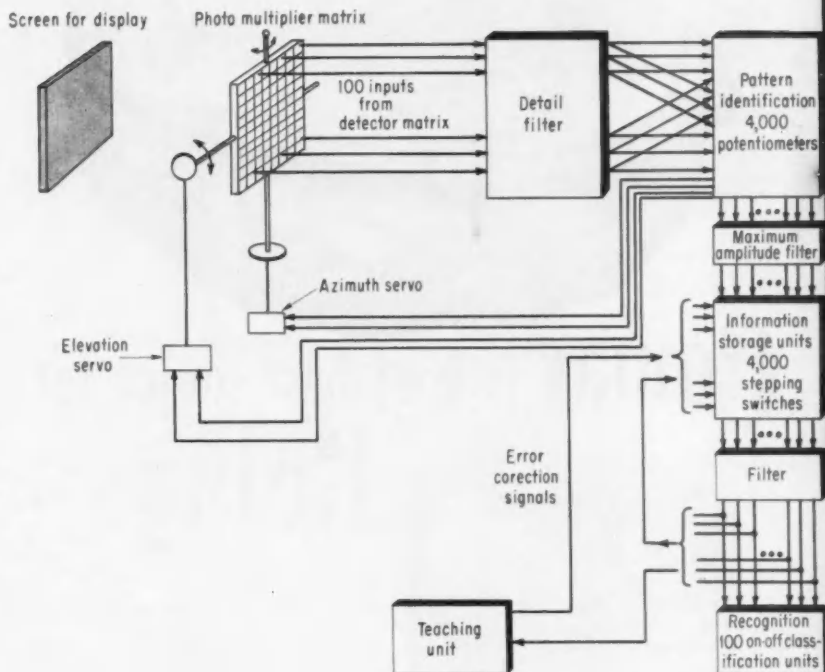
LONDON—

At London's University College, Dr. W. K. Taylor is building an unusual \$100,000 machine that soon will be able to recognize patterns under varying illumination intensities, even when the pattern size and shape varies. Based on a principle akin to human perception, the machine operates solely on analog signals, switching to digital at the machine's output to classify patterns.

Main components of Taylor's machine are a 10 by 10 photomultiplier sensing matrix, a summation unit with 4,000 potentiometers, an information storage unit composed of 4,000 stepping switches, and an on-off classification unit. A previous experimental unit with a 3 by 3 photomultiplier matrix and 16 capacitor-type storage units worked so well it was able to identify a typewritten T 100 percent of the time, even when the letter was tilted at an angle of 20 degrees.

• **Kin to Perception**—At first glance, the method of operation is quite similar to the Perception, the pattern recognition unit built at Cornell Aeronautical Laboratory under Dr. Frank Rosenblatt's supervision (CtE, Oct. 1960, pp. 28-29). Each of the 4,000 summation potentiometers is connected in an exclusive manner to the 100 outputs of the photomultiplier matrix. The voltage distribution on the 100 output lines, the result of viewing a pattern, characterizes what the machine has seen. One of the 4,000 potentiometers has a maximum output to uniquely identify the character viewed.

If the machine were to characterize completely the outputs of the 100 cell matrix, it would need 2^{100} potentiometer summing units. Taylor has reduced this to a practical number by discarding any units producing redundant information. As a result, each detector element in the matrix



covers a unique area.

Taylor's machine, therefore, will imitate the configuration of the retina in the human eye. Resolution will decrease as the distance from the central area of highest resolution increases. The area covered by each photomultiplier positioned along the horizontal and vertical axes doubles as the distance from the center increases.

A detail filter, placed between the summing units and sensing matrix, emphasizes signals received from the edges and corners of the pattern. Taylor considers such signals more important for recognition than others. His filter is made up of banks of summing amplifiers with the outputs of each feeding back to the inputs of all others.

• **Recognition**—When a character is flashed on a screen for recognition, the photomultipliers sense the existence of light and dark areas, pass signals onto the detail filter which emphasizes key recognition features such as edges and corners. Leaving the filter, the signals, some negative and some positive, feed into the summing amplifiers. When the sum of the

inputs to a specific amplifier are positive, they add to produce an output proportional to the number of inputs; when the sum is negative, the output is zero.

Which summation unit has the maximum output is identified by a second filter that generates a voltage on a line associated with the unit of maximum output. The special information storage units then classify the character into a category, just as the mind groups what the eye sees by association with similar or identical patterns stored in the human memory.

Taylor's machine uses the integrated output of the amplitude and duration of the maximum output filter to drive stepping switches that are coupled to a potentiometer. Variation of the potentiometer settings increases or decreases the attenuation constant in one of the paths between the filter output and the final 100 classification outputs. The path with minimum attenuation is energized, thus completing recognition.

• **After training**—To train the machine, an "instructor" decides which classification unit is to be associated with a particular character. At the

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WHAT'S NEW

start of training, all the potentiometer pathways are positioned randomly. When the machine views the character, the transmission of one path is altered; simultaneously, the instructor closes the classification switch associated with that character, sending a reinforcement signal to the memory.

Once the machine has been trained to recognize a specific set of patterns, Taylor thinks the potentiometers can be removed and replaced by resistor attenuator networks which would be equivalent to the potentiometer settings but quite inexpensive. Thus the inventor sees a need for a general purpose recognition device—to recognize new patterns, and a special purpose machine that would identify the same patterns over and over again.

Because of the flexibility of his approach, Professor Taylor envisions some startling applications for his pattern recognition machine. For example, he hopes to investigate face recognition. The London scientist thinks he may be able to characterize the human face into a number of different basic categories. If he can do this, says Taylor, there is no reason why the machine will not be able to recognize photos of men.

—Derek Barlow

Hungary Hosts Measurement Conference in Limited Quantities

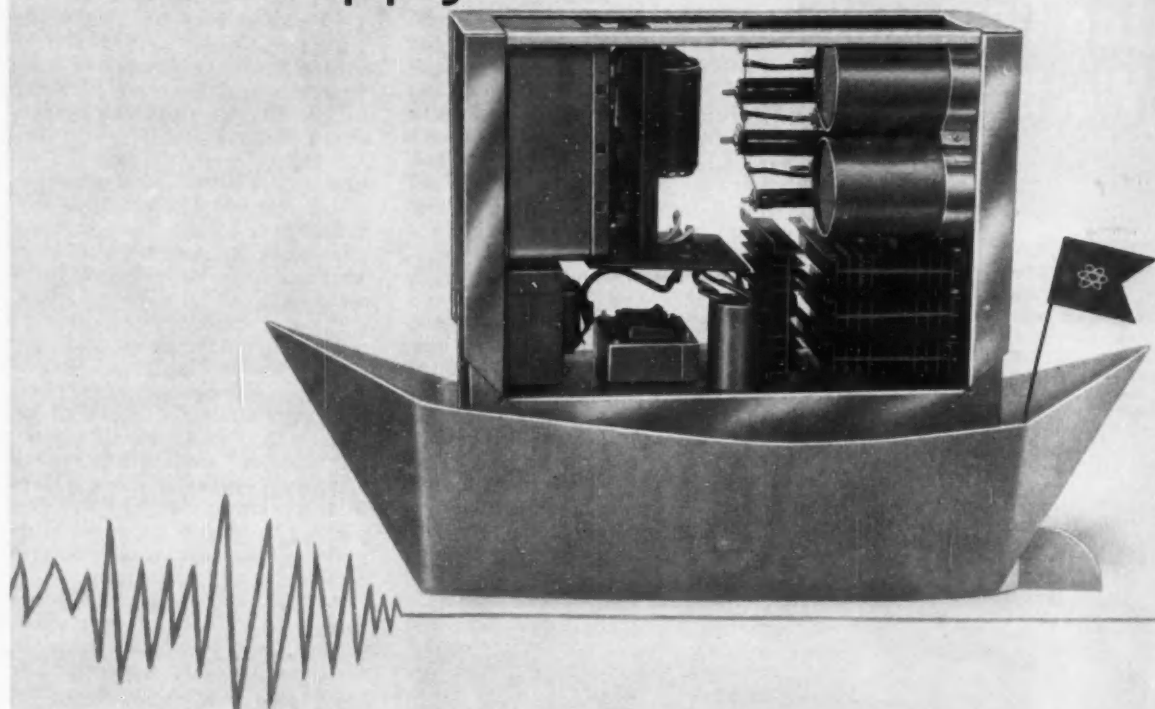
BUDAPEST—

The Second International Measurement Conference (IMEKO) will be held here from June 26 to July 1, 1961. At the same time an "International Preparatory Committee" approved 117 papers for presentation, the group decided to limit attendance to 700, setting quotas for each country.

United States attendance has been limited to 20; other quotas indicate that this is a meeting primarily for Soviet bloc countries. For example: USSR's quota is 75; East Germany's is 75 although West Germany's was reduced to only 30; Poland may send 75 representatives and Great Britain can send only 20.

From further study of the origin of papers and attendance quotas, it appears that one purpose of IMEKO is to educate Hungarian instrument engineers who have been assigned the role of measurement specialists in the Communist bloc's economic program. Although 195 Hungarians will attend the conclave, only 15 papers will be presented by Hungarian measurement specialists.

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The Controversy Over Project Turnkey

Turmoil over new mechanized post of office has engineers asking questions: is the fuss just politics or are some fundamental mechanical deficiencies behind it? Investigation shows there are some lessons to be learned.

WASHINGTON, D. C.—

Ask the new Postmaster General J. Edward Day what he thinks of the Post Office Dept.'s new experimental mechanized post office at Providence, R. I., and he'll sum up his feelings in the terse expression, "It doesn't work." Ask employees at the controversial post office and they'll tell you, "It works fine; there have been some bugs but we're getting them worked out as fast as we can."

Since the new mechanized equipment at Project Turnkey has been operating only three months—and some of that time under adverse conditions—sufficient time may not yet have elapsed to decide who is right. One thing seems sure, however, the startup of the complex system has not proceeded as smoothly as expected.

Washington experts tell you that most of what you hear from the new postmaster general is political, designed to embarrass the outgoing administration as acutely as possible. And indeed, reporters have been hard put to get specific information pinpointing what has been wrong at Providence. Prime contractor on this installation, International Telephone & Telegraph Corp. has been just as adamant that the mechanized equipment has worked as well as expected.

To paint an unbiased picture of what is happening at the Providence Post Office, CtE set three reporters to work investigating the controversy: one in Providence, one in Washington, and one in New York. Their conclusions: despite the political questions, there are some lessons for control engineers to learn from the troubles of ITT at Providence.

• **Political football**—At least some element of national politics is involved in the criticism of Project Turnkey. Rep. J. Vaughan Gary (D-Va.), Chairman of the House Treasury-Post Office Subcommittee, has accused the project of having "failed miserably to meet expectations". His committee has launched a congressional investigation into the matter.

Local politics seem to be involved too. The present postmaster of Providence is scheduled to retire soon, and there's a war of nerves underway among a flock of his subordinates who

would like to be his successor.

• **Technical bugs**—But not all the complaints revolve around political situations. CtE's reporters found that some of the troubles can be traced back to systems engineering deficiencies. For example:

► Post Office management did not have a clear idea of what the mechanization would accomplish; in fact, there is good evidence they had oversold themselves, expected miracles of what was really semiautomatic equipment.

► Man-machine relationships have not been solved completely. Although some of this equipment had been installed in Europe and other pieces have been working at the Washington, D. C., Post Office, virtually all the problems are combinations of human and mechanical failings. There is some evidence that the Post Office will not be able to retrain all of its workers, particularly the older ones, to operate the new equipment.

► Some mechanical deficiencies have to be worked out; some minor redesign is needed on a few machines; some new procedures may have to be worked out. For example, the sorting machine is mangling mail, maybe 25 to 40 letters a day, because the mail is not being removed fast enough by clerks. Warning lights might prevent this.

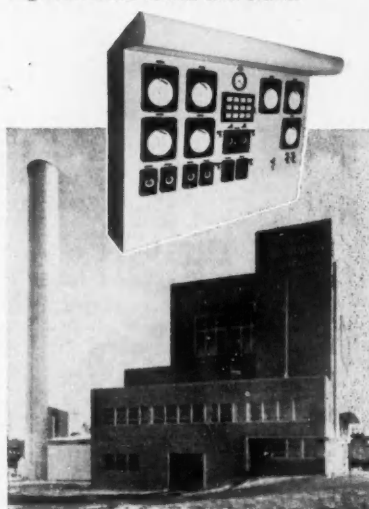
► The Post Office Dept. may not be using the system to the extent possible. In original plans the Turnkey post office was to handle mail from 180 post offices in Rhode Island and southeastern Massachusetts. Currently it is receiving mail from only 11 Providence district stations. Both Post Office employees and ITT have been asking for more mail. Average volume now is running about 400,000 letters per day; the system was designed to handle 1.3 million pieces of mail per day. It is possible that this year's unusually heavy snows have slowed the Post Office's plans to use the system.

• **Oversold**—One of the best publicized "deficiencies" of the post office has been the inability of six electronic facer-cancellers to distinguish between valid U. S. stamps and any other kind.

Carrier Linde
PERMUTIT
DUPONT
Judging by
the Company
We Keep...
Electro-Mech

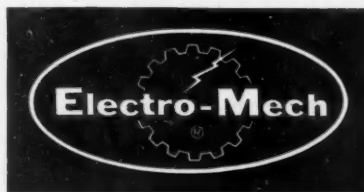
THE COMPANY WE KEEP—
also includes many municipalities.

To meet the pressing need for more efficient community facilities, Electro-Mech Corporation has been called upon repeatedly as an authority, specializing in the field of design and manufacture of control systems for Water Treatment, Sewage Treatment and Incineration . . . vital aspects in the health and welfare of our expanding American towns and cities.



If you are looking for Control Systems engineering, design assistance, or control center manufacturing facilities, we invite you to join the "Company We Keep" Contact ELECTRO-MECH.

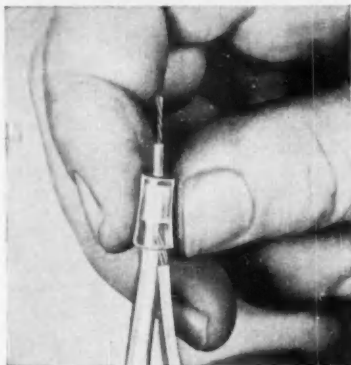
Electro-Mech Corp., Norwood, N.J.





WIRE AND CABLE

ROUND TABLE



One-piece Burndy connector gives fast, reliable compression

Fast and reliable connections are possible with the one-piece UNIRING, molded of ZYTEL by the Burndy Corp., Norwalk, Conn.

Since these are compression connectors, there is no heat needed, and thus no danger of overheating cable. This also means no slow, bulky solder joints. The completed UNIRING assembly is only a few mils larger than the cable diameter.

UNIRING is available both insulated and uninsulated for single shielded cables, multi-conductor shielded cable and coaxial cables. They are also color coded for easy identification.

The Burndy sheath connectors are another example of the versatility possible with ZYTEL nylon resins. For more information to help you evaluate ZYTEL for your needs, write to the address at the right of this page.

Du Pont does not manufacture wire and cable, but supplies thermoplastic resins to the wire and cable industry.

POLYCHEMICALS DEPARTMENT



Better Things for Better Living...through Chemistry

New shipboard control cable uses ZYTEL® for resistance to cut-through, chemicals and moisture.



This naval destroyer, the USS Wilkinson, is equipped with modern, anti-submarine missiles controlled by cables protected with Du Pont ZYTEL nylon resin. (OFFICIAL U.S. NAVY PHOTO)

ZYTEL 33 and 37X help protect the Navy's "MOHOS" cable used to control the Mark 108 rocket launcher on the USS Wilkinson. In this new cable design, each single has a thin secondary insulation of clear ZYTEL 33, plus a tough outer armor of heat and light stabilized ZYTEL 37.

The two layers of ZYTEL are used for several important reasons. The armor protects the entire cable and allows it to be easily pulled through cableways without snagging or skin-back. The two layers also provide outstanding resistance to cut-through, moisture and various hydraulic fluids to which the cable is exposed.

Because of the superior mechanical

properties of ZYTEL, the jacketing is thinner than other materials could be, reducing the overall cable weight and diameter. The secondary insulation of ZYTEL 33 permits the effective use of watertight terminal lugs to prevent wicking. And its transparency allows easy reading of identification matter printed on the singles.

You may find that the use of ZYTEL nylon resins or other Du Pont wire and cable grade plastics can solve your problems. If you would like more information, consult your wire and cable supplier, or write to the Du Pont Company, Dept. CE-4, Room 2507Z, Nemours Bldg., Wilmington 98, Delaware.

ALATHON®
POLYETHYLENE RESINS

RULAN®
FLAME-RETARDANT PLASTICS

ZYTEL®
NYLON RESINS

IDEAS → (D) → (S) → (E) → PRODUCTS

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DIGITAL & ANALOG INSTRUMENTS & CONTROL
HARDWARE, ENGINEERING, SYSTEMS & SUBSYSTEMS

ACCURATE, RELIABLE, ECONOMICAL

PRODUCTS:

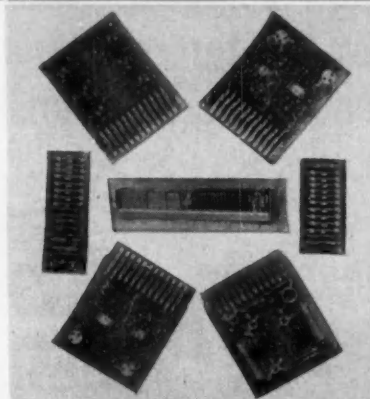
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METERS

DIGITAL-ANALOG
CONVERTERS

ANALOG-DIGITAL
CONVERTERS

OPERATIONAL
AMPLIFIERS

DIGITAL MODULES



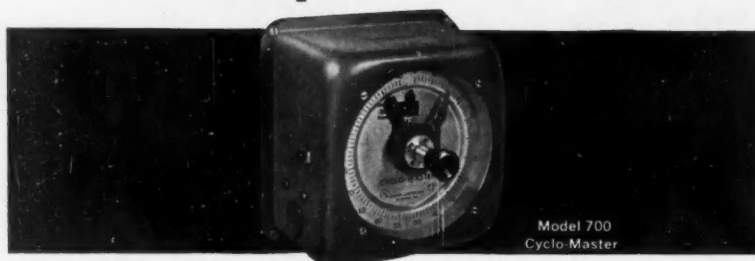
2001 N. SCOTTSDALE RD.

SCOTTSDALE, ARIZ.

CIRCLE 236 ON READER SERVICE CARD

STANDARD
MODEL FOR

ONE-COUNT SWITCHING
ONE-CYCLE SWITCHING
DIFFERENTIAL COUNTING



Model 700
Cyclo-Master

use the new **Cyclo-Master**

continuous cycling preset counter and controller

- Counts electric impulses at speeds up to 1000 cpm
- Single-knob dial settings from 1 to 100 counts
- Recycles with absolutely no interruption of counting process
- Quick manual reset to zero • Wall or panel mounting
- **Applications in control of:** automatic reversing, batch counting, box-making machinery, container filling, instrumentation, punch press cutoff, roll sizing, sheet counting, paper converting machinery, packaging machinery, interval indication, linear measuring, adding and subtracting to preset maximum and minimum limits, etc.

WRITE FOR BULLETIN 700

COUNTER and CONTROL CORPORATION

4509 WEST BROWN DEER ROAD • MILWAUKEE 23, WISCONSIN

WHAT'S NEW

The machines pass foreign stamps, trading stamps, and Christmas seals. It is an example of a misunderstanding of what the system was to do. In truth the equipment was never intended to differentiate between valid and counterfeit stamps; its sole purpose is to indicate whether a stamp is present or not and how the envelope is turned so it can cancel the stamp.

A serious defect of this equipment, however, has been its determination to reject window envelopes. Because it operates on an optical light sensing principle—with photocell scanning to spot the stamps—the device rejects mail when the light hits a glassine window envelope that has been cut too low. Rejection rates for this reason have been running anywhere from 30 percent (claimed by the post office) to 15 percent (admitted by IT&T).

Of course a certain amount of this mail is supposed to be rejected. The electronic machines cancel only "average-sized" envelopes. All others are rejected for hand cancelling.

• **Tired man**—At least one part of the mechanized system has had difficulty meeting the specifications of performance: the semiautomatic mail sorter, of which there are six at Providence. Letter mail is moved in front of an operator who reads the address, then punches in a three-key code to automatically sort the letter into the proper continuously moving bin. Each operator is supposed to be able to sort 50 letters per minute. But the pace has been too gruelling for some operators. And others have been too slow learning the code.

ITT points out that the machines have worked at this rate in Europe and at the Washington, D. C., Post Office where they have also been installed. In Washington, young girls were hired and specially trained to run the machines. At Providence the Post Office retrained men who were mail handlers or even letter carriers to operate the equipment. It indicates, said an ITT spokesman, that retraining postal clerks to use mechanized equipment may not be as easy or as practical as expected.

• **Mangled letters**—One other problem with the sorter has been the tendency to mangle a handful of letters each day because the continuously moving bins are not emptied. The way the system works a mail clerk is supposed to take the package of letters from a bin when it fills up—capacity is 50 letters. But if he turns away from machine or leaves it for any

(Continued on page 198)

PROVED ULTRA-RELIABLE VICTOR DIGIT-MATIC PRINTERS



160,000,000 digit impressions without failure

Rugged, Trouble-Free—Digit-Matics are specially built to stand the strain of continuous operation. In a durability test, over 160 million digit impressions were made without breakdown or need of adjustment. The machine tested operated continuously, eight hours per day until 160 million digit impressions were made. During this period only normal lubrication and cleaning were performed.

Parallel or Serial Entry — Automatic and unattended, solenoid-activated Digit-Matics print out alpha-numeric data from remote equipment. High speed parallel entry models accept up to 10 digits at a time, print up to 4 lines per second. Serial entry models accept 1 digit at a time, up to 11 per line.

Two-Color Printing — Positive values in black, negative values in red. Ideal for "accept-reject" sequences, testing applications, accumulating data from two sources on one Digit-Matic, and many other uses.

Adaptable to Your Specific Needs — Line includes listers, accumulators and calculators. Versatile units can handle degrees, minutes, seconds, fractions. Other modifications: superimposed keyboard for manual use, time readings, counters, etc.

Immediate Field Service — 70 factory service branches and service representatives in over 600 cities assure uninterrupted operation. Victor offers 30-day delivery on most Digit-Matics. Mail coupon now for product data and application information.

VICTOR ELECTRONICS DIVISION

Victor Adding Machine Co., Chicago 18, Illinois
Victor Adding Machine Co., (Canada) Ltd., Galt, Ont.
*Manufacturers of Digit-Matic Printers, Scanning Printers,
Electrical Keyboards, and Digit-Matic Data Punches*

Victor Adding Machine Co.
Chicago 18, Illinois
Send full information on Victor Digit-Matics.

CE-4

My application is _____
Name _____ Title _____
Company _____
Address _____
City _____ State _____

YON DESIGN ENGINEER HATH A WOEBEGONE LOOK —PRITHEE, WHY?



Ah, therein lies a most tragic tale. Yon design engineer hath created — out of his own imaginative genius, mind you — that miracle of miracles, that *sumum bonum* —

You mean —?

Precisely. I mean a better chronodigitator.

Come, come! If this engineer hath indeed created a better chronodigitator, why doth he not sing for sheer joy, why not click together his heels just for the — uh — heck of it? Why is he *woebegone*?

'Tis a sad story.

Out with it, man!

Methinks his chronodigitator is too good to be true. He hath envisioned a super-chronodigitator which requires, alas, a multiple-program, adjustable cycling timer.

This super timer must be able to change program sequence and timing, in minutes with standard parts, even after installation. It must synchronize the operation of as many as twenty independent load circuits, with OFF-ON switch points field adjustable to factory standards! Yet, woe is he, its cost must not be out of this world. Now where, sire—?

Where can he find such a timer? Ah-ha, and possibly ho-ho! At a manufactory yecept Cramer Controls Corporation in Connecticut.

They will provide him with their Type

CRAMER CONTROLS CORPORATION

ELECTROMECHANICAL DIVISION • CENTERBROOK, CONNECTICUT

50 CIRCLE 50 ON READER SERVICE CARD

540 timer in any of hundreds of different speeds to give timed actuations from the first second to the twelfth-night and beyond. Plus a neat little wench — er *wrench* — to change cam settings and a big vernier knob to assure precise operations — within one-half of one per cent of full cycle time — right in the field. Ha! Even the actuator is adjustable!

What? I didst know this Cramer Controls Corporation as a most excellent company, unequalled for synchronous timing motors, miniature direct current motors and elapsed time indicators, but —

But me no buts! Instead, fly to yon design engineer, tell him to be *woebegone* no more. At Cramer he will find control magicians! A research and development group after his own heart — creative, imaginative, ingenious!

Forsooth!

Tell him if he but write, a man from Cramer will be at his desk or drawing board forthwith! A man of great *savvy* (prithee pardon the expression) in precisely such problems as his.

I fly!

Wait! Tell him also to write for the data-filled bulletin PB-540. Posthaste!

Zounds! You have helpt give birth to a new and better chronodigitator.

What else?

1 Cramer precision drive motor

...high torque, truly synchronous operation, instant stop-start.

2 Precision-hobbed gear linkage

...inexpensive gear rack permits various speeds from same motor.

3 SPDT load switches

...from 3 to 20, rated 10 amps, in molded plastic shells each attached by one screw.

4 Precision-cut cams

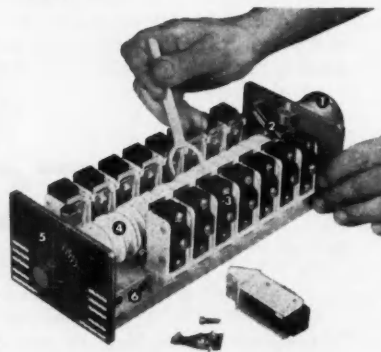
...split design, easily adjustable from 2% to 98% of full rotation.

5 Vernier dial

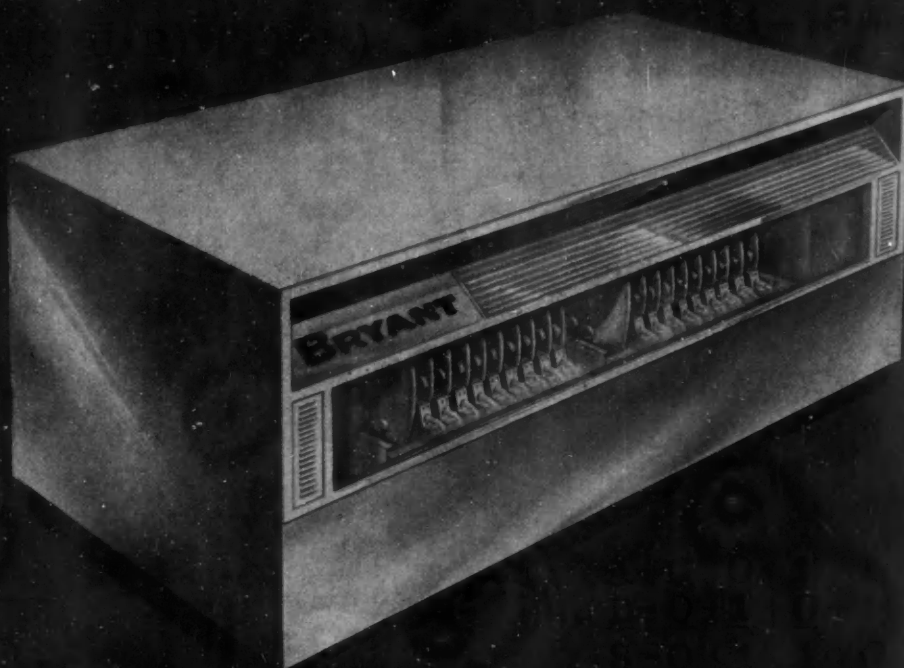
...achieves field-setting accuracy of 0.5% of full cycle time.

6 Extruded aluminum base

...acts as conduit to protect all switch wiring.



CONTROL ENGINEERING



BREAKTHROUGH FROM BRYANT

MODULAR MASS MEMORY

Random Access
600,000,000 Bit Capacity
30,000,000 Bit Modules

The new Bryant Series 4000 Disc Files incorporate all of the advanced engineering and design concepts responsible for the success of the already-delivered prototype . . . plus modular construction to provide tailor-made solutions to a wide range of mass memory requirements. Among the features are:

- Simultaneous positioning of 240 heads in 100 milliseconds.
- Choice of either parallel or serial recording.
- Digitally-addressed, mechanical positioner.
- Guaranteed positioning accuracy.
- Selective alteration of information.
- Discrete clocking.
- Guaranteed microfinished recording surfaces.
- Advanced electronic design—rugged mechanical construction.



COMPUTER PRODUCTS

Disc File and Magnetic Drum Memories for Every Storage Application
852 Ladd Road • Walled Lake, Michigan • Market 4-4571

A DIVISION OF EX-CELL-O CORPORATION

61-36-CP

APRIL 1961

CIRCLE 51 ON READER SERVICE CARD

51

NEW FROM WESTINGHOUSE AT YOUNGWOOD



New Westinghouse High Gain Transistor simplifies circuitry, increases reliability, eliminates driver stage components, reduces cost of assembly.

NEW WESTINGHOUSE SILICON POWER TRANSISTOR PROVIDES

GAIN OF

Westinghouse introduces a complete new family of High Gain Silicon Power Transistors providing a gain of 1000 or more at 2 amps . . . with guaranteed minimum gain of 400 at 10 amps (WX118X series) . . . a guaranteed minimum gain of 100 at 10 amps (WX118U series). These devices can substantially reduce circuit components, increase reliability, save space and weight.

They're ideal for application in high power, high efficiency regulators, amplifiers and switching circuits. For example, 1500 watts of power can be easily controlled with a 50 milliwatt signal! For full information call your nearest Westinghouse representative or write to Semiconductor Dept., Youngwood, Penna. You can be sure . . . if it's Westinghouse.

SC-1025

OTHER FEATURES INCLUDE

- True Voltage Ratings to 150 volts
- Power dissipation of 150 watts
- Collector current—10 amperes
- Operating temperature to +150°C.
- Low thermal impedance: .5°C/watt

1000 AT 2 amps!

Prototype quantities now available. Order from these Westinghouse Distributors.

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HALLMARK INSTRUMENTS CORP.
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Westinghouse

CIRCLE 53 ON READER SERVICE CARD

IT CAN HAPPEN HERE



"My dear son

I am so sorry you are going to
have to live under Communism.

It seemed to come so quickly.

I didn't think their lies could win.

I guess we were so busy
with other things.

Not enough of us spoke up for
freedom when we had the chance."

You can speak up for freedom right now

Your dollars are needed to help build the American Freedom Center at Valley Forge. You can speak up for freedom by contributing Freedom Bricks.

The Freedom Center will provide research and library facilities for all individuals, groups and organizations seeking to defend and interpret the free American system. It will house the award-winning materials of over one million entries in Freedoms Foundation's eleven annual National Awards Programs.

Freedoms Foundation was founded in 1949 to help maintain the American Way and pass it on intact to each generation. You can strike an effective blow *against communism* by joining Freedoms Foundation's FOR AMERICANISM program. The Foundation is nonprofit,

nonpartisan, nonsectarian. Membership is open to all patriots. Dwight D. Eisenhower is Honorary Chairman.

FREEDOMS FOUNDATION
VALLEY FORGE, PA.



Yes, I want to help build The American Freedom Center.
Here is \$_____ for _____ Freedom Bricks at \$1 per
brick.

I am enclosing \$_____ as an additional contribution
to make me a member of Freedoms Foundation.

Name _____

Address _____

City _____ Zone _____ State _____

This advertisement published for FREEDOMS FOUNDATION as a public service by CONTROL ENGINEERING



THE SPACE JOURNEY THAT BEGAN WITH AN



INDUSTRIAL TIMER



INTERVAL TIMERS



TIME DELAY TIMERS



RUNNING TIME METERS



RECYCLING TIMERS

The first space shot with living creatures that returned alive is now history—a significant milestone in the conquest of space.

The two monkeys, placed aboard the rockets to help scientists gather data on the probable effects of space travel on man, received unique training on the apparatus pictured above.

They were conditioned to manipulate the lever in response to timed stimuli, governed by a 4-unit tandem of Interval Timers by Industrial Timer Corporation.

This is not the first time our products have been used in medical and psychological projects. However, they are more commonly found where precise, reliable timing of industrial processes is vital.

Send for literature describing the comprehensive line of Industrial Timer Corporation Timers for every industrial application.

CIRCLE 55 ON READER SERVICE CARD



INDUSTRIAL TIMER CORPORATION

1403 McCarter Highway, Newark 4, New Jersey

Manufactured and sold in Canada by
SPERRY GYROSCOPE OF CANADA, LTD., OTTAWA, CANADA

Servo Power satisfies more

in Taylor *TRANSCOPE® Electronic and Pneumatic*

Powerful SERVOMATIC motors in Taylor TRANSCOPE Recorders not only give you greater recording accuracy than ever before, they also supply the power necessary for precision operation of auxiliary mechanisms and computing devices. Power in the pneumatic servo is 150 times greater than the bellows type; in the electronic it's 1,000 times greater than galvanometer systems.

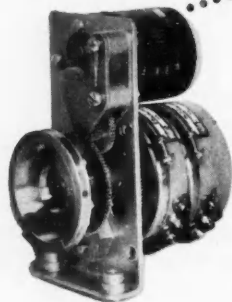
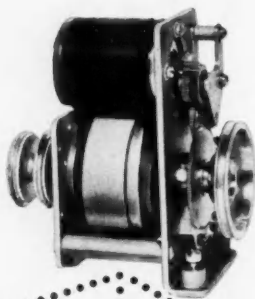
This means closer measurement of temperature, pressure, flow, flow ratios, pH and other process variables—whether the signals are pneumatic or electric. Accuracy of ½ of 1% is standard, ¼ of 1% optional.

You economize with servo power because you no longer need conventional "black boxes" for auxiliary functions. You save on panel space . . . and installed cost.

Optional features made possible by servo power include integral process alarms, retransmitting potentiometers, function generation and digital output with encoder discs. Ask your Taylor Field Engineer to demonstrate the built-in plus value of servo power in the TRANSCOPE line. Or write for **Bulletin 98286** (Pneumatic) or **98335** (Electronic). Taylor Instrument Companies, Rochester, New York, or Toronto, Ontario.

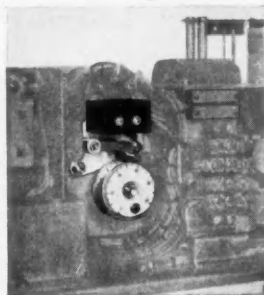
700J ELECTRONIC SERVO MOTOR

Precision gearing couples servo to a precise feed-back device with high torque. Built to military specifications.



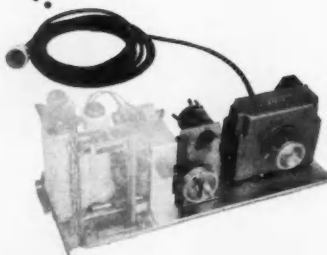
RETRANSMITTING POTENTIOMETER

permits numerous computations such as xy , $\frac{x}{y}$, $\frac{xy}{z}$, \sqrt{x} .



INTEGRAL ALARMS

cost approximately 1/3 as much as conventional external "black boxes".



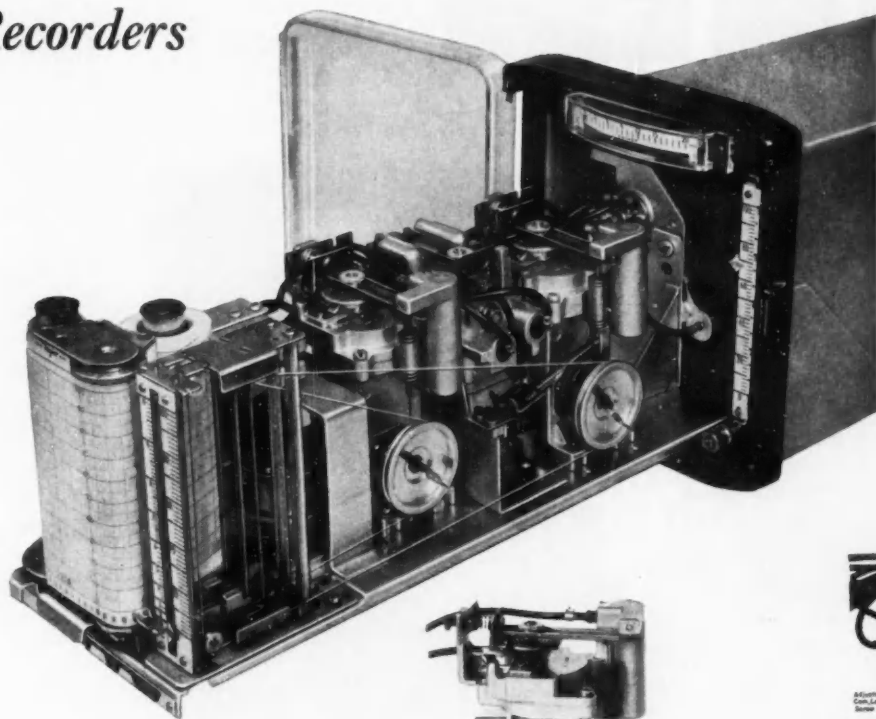
DIGITAL ENCODER

—servo motor permits use of compact, high accuracy, integral encoders.

Taylor Instruments

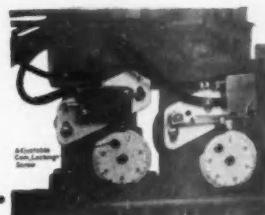
process needs more economically

Recorders



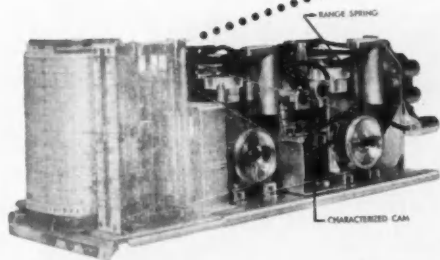
90J PNEUMATIC SERVO MOTOR

Essentially a power piston with built-in positioner. Solid construction assures long, trouble-free life.



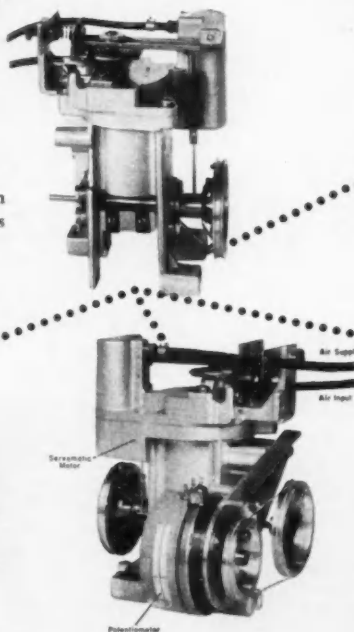
INTEGRAL ALARMS

Alarm points convenient to set on calibrated dials.



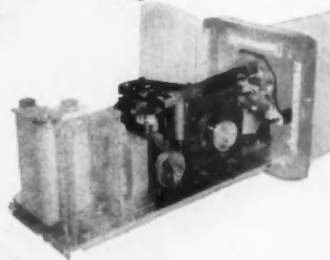
FUNCTION GENERATOR

puts square root extraction and other similar functions within recorder.



POTENTIOMETER

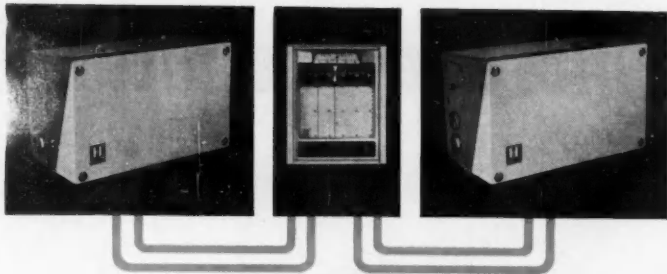
costs about half as much as usual "black box" transducers.



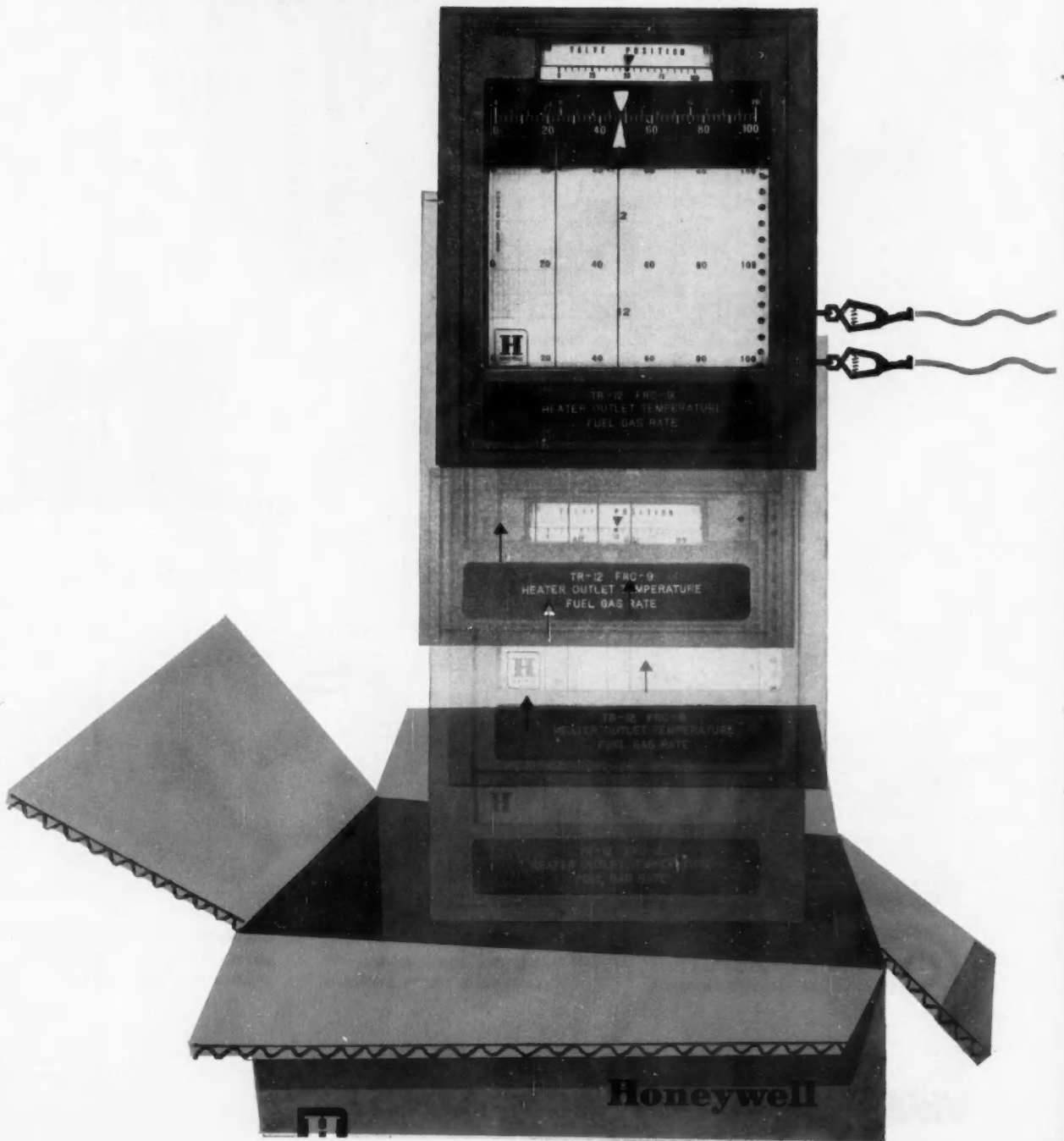
DIGITAL ENCODER

sets new standards of accuracy for pneumatically driven encoders.

MEAN ACCURACY FIRST



ElectriK Tel-O-Set—the true 2-wire system



This "Loop Snooper" adds to the extraordinary ease of installation and maintenance you'll find in the *ElectriK Tel-O-Set* System. It's a portable test instrument that can accurately check . . . from the control panel . . . any *Tel-O-Set* unit in the field, to make sure signals are being received and sent exactly as they should be. Or it can operate and check a recorder chassis, indicator chassis or controller on the bench, with local power. The "Loop Snooper" removes trial and error from installation and maintenance.



SIMPLEST TO INSTALL, ADJUST AND MAINTAIN

The *ElectriK Tel-O-Set* System has many features that save time in getting on stream, and keep maintenance to a minimum. For example, all process connections are isolated from the inside of *Tel-O-Set* transmitter and transducer cases, so that you can mount, pipe and wire the instruments without removing their covers. Instrument chassis can be removed for servicing without breaking any external process or electrical connections. Standardized parts and extensive use of quick-connect and plug-in design cut downtime and spare parts requirements.

No external power is required at any field-mounted *Tel-O-Set* instrument; line power is connected only

at the receiver. Two-wire d-c transmission eliminates shielding and further reduces installation costs. The 4-20 milliamp signal range gives a *live* zero through the use of readily available reliable transistors.

Your nearby Honeywell field engineer can tell you how *ElectriK Tel-O-Set* advantages relate to your particular control requirements. Call him today . . . he's as near as your phone. Or write to MINNEAPOLIS-HONEYWELL, 21 Penn Street, Fall River, Massachusetts.

Honeywell



First in Control
SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

APRIL 1961

CIRCLE 59 ON READER SERVICE CARD 59

WORKING ON OUR second million



OVER 1,000,000
PANALARM
ANNUNCIATORS
are in process
industry
operations

More Panalarm Annunciators are specified and used because of:

Assured Reliability due to:

- 100% Inspection for all components, both in production and final assembly.
- Complete testing of each annunciator system before shipment.

Assured Reliability due to:

- Ultrasonic cleaning.
- No in-service gassing—moisture and destructive volatile materials eliminated by high vacuum oven baking.
- Plug-ins are filled with inert gas and hermetically sealed under pressure.
- Extra safety margin for Class 1 Division 2 applications provided by electronic halogen leak detection.
- After millions of operations, max. continuous contact pressure and uniform gap spacing are assured by beryllium copper contact springs.
- Hi temp cured TEFLON-covered coils.

Panalarm maintains a large staff of annunciator engineering specialists to assist with special annunciator design and application problems. Sales and engineering offices are in all principal cities. Your inquiry will receive prompt attention.



DIVISION OF ISI INCORPORATED

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Annunciators • Control Panels • Data Systems

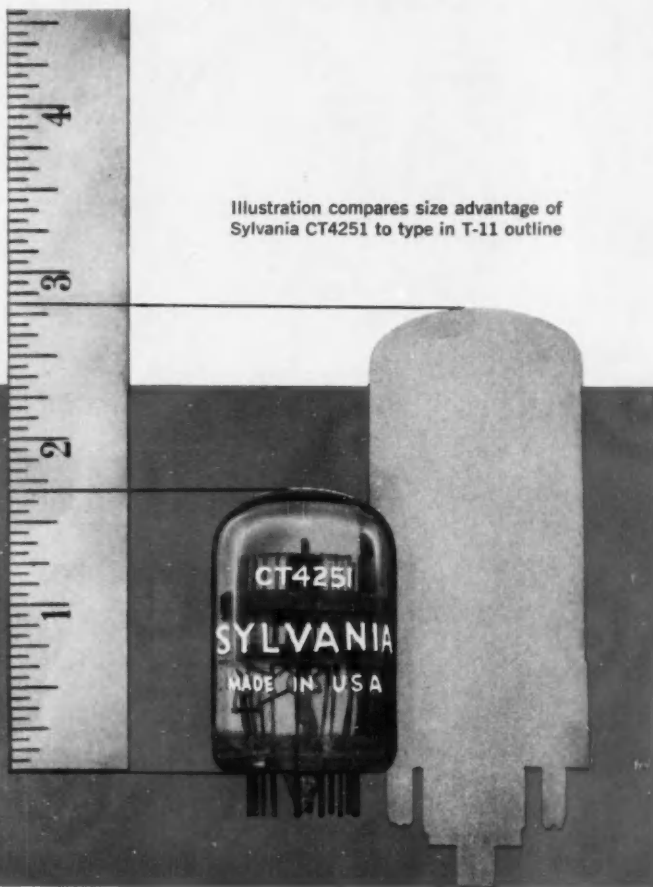
New! Sylvania CT4251

First

Compact

Decade Counter Tube
in Dome-Shaped T-9 Bulb
with 10 Output Cathodes

Illustration compares size advantage of
Sylvania CT4251 to type in T-11 outline



Sylvania introduces the new CT4251 . . . opening a dramatic new approach to the design of very compact, low-cost counting equipment in the 0-50KC frequency range.

Utilizing a new dome-shaped T-9 bulb evacuated from the base, Sylvania CT4251 offers significant reductions in seated height. CT4251 features 10 output cathodes, offering the versatility and advantages of tube types previously available only in the T-11 bulb. Examples: electrical information can be fed from all 10 cathodes, enabling preselection of a count from 0-9; the diameter of the ring of cathodes is identical with that of types in the T-11 outline, providing excellent visibility of readout information.

Sylvania CT4251 is the lowest cost *cold cathode Decade Counter Tube* available. Combining electrical and visual readout functions, it offers extensive economies in circuitry and associated components. Sockets, too, for its 13-pin

circle are as much as one-half the cost of sockets normally required for T-11 types. In addition, this new 13-pin circle makes it possible for Sylvania CT4251 to be designed into equipment using transistorized and printed circuit techniques. Tests to date of Sylvania CT4251 indicate superior quality performance even under stand-by operation for 500 hours. Your Sylvania Sales Engineer will be pleased to tell you more. Contact him or write Electronic Tubes Division, Sylvania Electric Products Inc., Dept. 134, 1100 Main St., Buffalo 9, N. Y.

Sylvania Type	Total Anode Current (mA)		Min. Anode Supply Voltage (Vdc)	Min. Double Pulse Amplitude (V)	Min. Double Pulse Width (μsec)
	Min.	Max.			
CT4251	0.65	0.8	400	-70	4

SYLVANIA

SUBSIDIARY OF

GENERAL TELEPHONE & ELECTRONICS



PROGRAM		SAMPLE CUSTOMER ORDER RUN USING A COMBINATION OF COBOL, TABSOL, AND ALGOL		DATE	
PROGRAMMER		COMPUTER		GE 225	
SEQUENCE NUMBER					
305		OPEN INPUT MASTER~SPEC, CUST~SPEC, AND PARAMETER FILE			
310		READ PARA~CARD RECORD.			
315		GET~SPEC. READ CUST~SPEC RECORD, AT END FILE GO TO END~			
320		READ MASTER~SPEC RECORD UNTIL ORDER~NO OF MASTER~SP			
325		ORDER~NO OF CUST~SPEC. AT END FILE GO TO END~ROUT			
330		IR = SQRT (A**2 + B**2). MOVE A1 TO A. MOVE B1 TO B			
335		K~SPEC TABLE. 3 CONDITIONS, 3 ACTIONS, 4 ROWS.			
340		K EQ	IR EQ	LOT~NO EQ	DRWG~NO
345		0.0763	0.00761	"AB33"	"5007AB33"
350		1.1127	0.3451	"C33"	"5010C33"
355		2.9001	0.7942	"F331"	"5020F331"
360		3.7667	0.81175	"AL331"	"5024AL331"
365		IF K~SPEC TABLE NOT SOLVED, DISPLAY "K~SPEC N.S." 0			
370		PERFORM AREA~P.			
375		SPEC~CALC. AREA(J) = P~AREA			
380		IF AREA(J) EQ P~AREA(L(I*3).M(Q+N,Z)) OR HOLE~NO NG			
385		PDZ = (A*B)**3 - SQRT AREA(J).			
390		IF J EQ Q-1 THEN GO TO GET~SPEC			
395		J = Q.			
400		GO TO COST~ADJUST.			

GECOM...A UNIQUE CONCEPT IN

now available in the GE 225...and future General Electric general-purpose computers.

- processes COBOL, ALGOL and TABSOL*
- all problem statements easily read and understood
- extended usage...re-programming unnecessary
- programs produced faster...more efficiently

GECOM—the first truly GENERAL COMPILER SYSTEM—introduces a fresh, versatile approach to computer communication. Developed for the GE 225 computer, the GENERAL COMPILER makes available all of the various proved programming techniques in one consistent, compact package. No longer is it necessary to learn a dozen different programming systems to handle a full range of jobs effectively—each job is approached in *exactly the same way*, be it formula evaluation, a sort, or even a payroll. The language for describing any run is *consistent*, operating procedures and programming are *standard*, and documentation is readable and easily understood.

*A General Electric Trademark

THE GENERAL COMPILER PROVIDES—

A FAMILIAR LANGUAGE STRUCTURE—Problems need not be stated in machine code. The GENERAL COMPILER processes English language statements (COBOL), Algebraic expressions (ALGOL), and Structure Tables (TABSOL). It permits you to use all or any one of the computer languages...as your needs require. Still, you have available the capability to expand, use other languages and new techniques as your needs change.

A PROVED, ACCURATE CODER—Data Description and Problem Logic may be written in one, two, or a combination of the available languages producing a machine program of efficient, effective coding. Since the machine coding is derived directly from the logic of the problem statement, it is only at the logic level that debugging may have to be done.

A STANDARDIZED, UNDERSTANDABLE DOCUMENTATION—Because GENERAL COMPILER problems are written in familiar languages, they can be easily read and under-

GENERAL ELECTRIC'S NEW 225 GENERAL COMPILER GECOM

COBOL

TABSOL*

ALGOL



Control Console and Central Processor of the GE 225 Information Processing System

COMPUTER COMMUNICATION

stood. In addition, problem format provides a high degree of standardization. Programs written for today's machines in GECOM format can be used for future General Electric computers—eliminating the need for re-programming.

AN EFFICIENT, ECONOMICAL USE OF COMPUTERS—Personnel training time and expense are sharply reduced since the novice programmer may use the familiar terminology of his profession. Manual coding is eliminated and debugging cut to a minimum. Thus, a machine program may be produced much faster and

more efficiently than by present manual methods.

THE GENERAL COMPILER IS ANOTHER GENERAL ELECTRIC FIRST!

For more detailed information, write today for brochure CPB-144 on the new General Electric General Compiler. Also available: brochure CPB-101 on the GE 225 Information Processing System and CPB-81 on the GE 210 Data Processing System.

Write to: General Electric Company • Computer Department • Section 60G4 • Phoenix, Arizona.

Contact Your Nearest General Electric Computer Department District Office: Atlanta: 270 Peachtree St. N.W., JA 5-5739 • Boston: 140 Federal St., HU 2-1800, Ext. 311 • Chicago: 840 S. Canal St., WA 2-5611, Ext. 587 • Cleveland: 215 Euclid Ave., SU 1-6822 • Dallas: 3200 Maple Ave., RI 8-0589 • Detroit: 680 Antoinette St., TR 2-2600 • Los Angeles: 1010 S. Flower St., DU 1-3641 • Louisville: Bldg. 6, Appliance Pk., GL 4-7511 • Minneapolis: 6th & Hennepin, FE 2-7569 • New York: 122 E 42nd St., PL 1-1311, Ext. 2235 • Philadelphia: 2 Penn Center Plaza, LO 8-8085 • Phoenix: 3550 N. Central Ave., AM 4-3741 • Pittsfield, Mass.: 100 Woodlawn Ave., HI 3-3511 • San Francisco: 235 Montgomery St., DO 2-3740 • Schenectady: Bldg. 2, 1 River Rd., FR 4-2211, Ext. 5-4405 • Seattle: 710 Second Ave., MA 4-8300 • St. Louis: 818 Olive St., GE 6-4343 • Syracuse: 3001 James St., GR 6-4411, Ext. 7125 • Washington, D.C. Area: 7401 Wisc. Ave., Bethesda, Md., OL 2-8100
In Canada: Canadian General Electric Co., Ltd., Electronic Equipment and Tube Dept., 830 Lansdowne Ave., Toronto, Ont., Canada. **Outside U.S.A. and Canada:** Producer Goods Dept., Int'l. General Electric Co. Div., 150 E. 42nd St., N.Y.C., U.S.A.



General Electric—Pioneer in computer systems for all phases of business, industrial, scientific, engineering and financial endeavor.

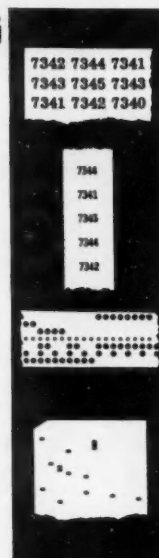
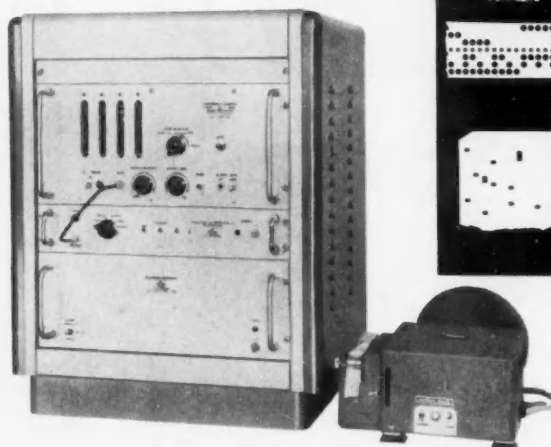
Progress Is Our Most Important Product

GENERAL  ELECTRIC

SIMPLIFY DATA HANDLING

*with a low cost, flexible system
that provides*

- *fast, accurate measurement*
- *variable measurement rate and range*
- *typewritten, printed, punched tape or punched cards*



Dymec Model DY-5552 Data Processing System is a remarkably versatile tool for quickly accumulating data on a wide variety of physical, mechanical and electronic processes. Any phenomenon of nature or science that can be converted to a usable voltage or frequency can be measured and recorded through the DY-5552. Digital output can be in any form or combination of forms needed for further machine processing, visual analysis or transmission over any standard communication system. Applications are limited only by the imagination.

The moderately priced Dymec system consists of a voltage-to-frequency converter and electronic counter to convert input information to digital form, plus a scanner/coupler, which transfers this digital data and is capable of providing output for electric typewriter, Flexowriter, serial-entry adding machine and serial entry card punch or tape punch. In many cases two of these recording devices can be operated simultaneously. In addition, the system can drive a digital printer, such as the Hewlett-Packard 560A.

This is one of many Dymec Data Processing Systems which can be assembled from basic "building block" instruments. Versatile, flexible input scanners, counters, digital voltmeters, output couplers/translators meet a wide range of needs for speed, multiple input application, programming.

BRIEF SPECIFICATIONS

Input Ranges:	0 to 1 v dc, 0 to 10 v dc, 0 to 100 v dc, 0 to 1,000 v dc (30% overrange permissible except on 1,000 v range; either polarity measured without switching). Frequency inputs, 1 cps to 120 KC. Gate times, 0.1 sec., 1 sec.
Accuracy:	DC inputs, .06%, ± 1 count Frequency inputs, .01%, ± 1 count
Operating Speed:	Controlled by Display Time Setting (variable from .1 to 15 sec. or indefinitely), maximum operating speed of 5 full scale readings per second.
Approximate price:	\$3,600.00 (as pictured, including tape punch).

Data subject to change without notice.

Prices f.o.b. Palo Alto

Describe your requirement today to your Dymec/Hewlett-Packard representative, write Dymec for further information or call Dymec direct. Extension 223 or 224.

DYMEC

A DIVISION OF HEWLETT-PACKARD COMPANY



7044

Dept. C-4, 395 Page Mill Road, Palo Alto, Calif. • Phone DAvenport 6-1755 (Area Code 415) TWX-117-U



CANNON MAGNETIC DEVICES

FULL RANGE OF SOLENOIDS AND ACTUATORS FOR MILITARY, INDUSTRIAL, AND COMMERCIAL APPLICATIONS

—Canon's complete line of magnetic devices—solenoids and actuators—meet all requirements for missiles, aircraft, digital computers, automatic calculators, high speed printers, data processing equipment and other electro-mechanical systems...standard, environmental, and specialized areas! Our magnetic devices are available in a wide variety of sizes and designs: mil spec, high performance, high speed, miniature and long life. Broad power ranges; input voltages in 6, 12, 24, 36, 115 and 230 ac and dc; reliable performance for any application, any environment. *And another first in the industry:* standardized nomenclature to assist you in finding the right device for your individual purpose. For complete information write to:

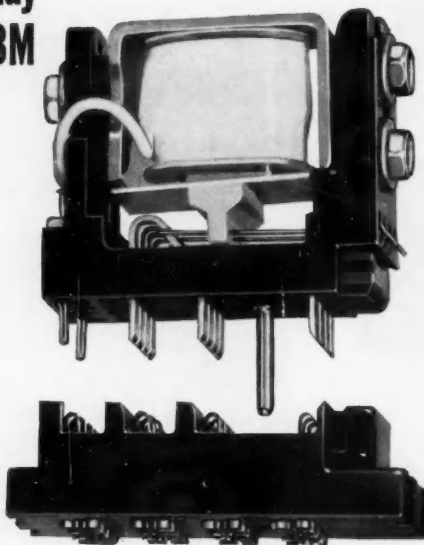
CANNON
 **PLUGS**

CANNON ELECTRIC COMPANY, 3208 Humboldt Street, Los Angeles 31, California

APRIL 1961

CIRCLE 65 ON READER SERVICE CARD 65

New Relay from RBM



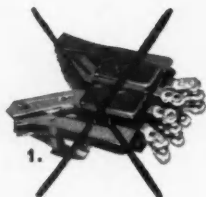
Compact, Rugged, Proven Reliable

THE DIRECTOR

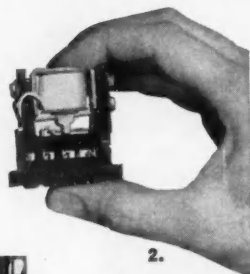
TYPE 81 WIRE CONTACT RELAY

Specifically designed to direct or set-up circuits in the logic or arithmetic section of computer and business machines. The RBM "Director" has also demonstrated itself ready to perform in similar applications where the basic function of the contacts of one or more relays sets up a circuit, but is not required to make or break that particular circuit. Typical uses would be controls for automation, railway signaling, traffic controls, chemical process controls, annunciators and many others.

Designed for high speed and long life (200 million operations).



1. No soldering



2.

Small Size



3.

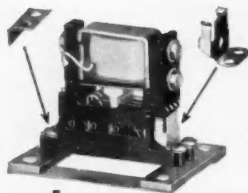
Wire contacts



"A"

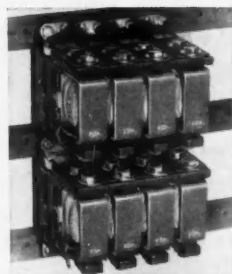
4.

Program connectors



5.

Rugged snap-in
plug assembly



6.

Rack mounting

1. Plug-in terminal and mating terminal block eliminates messy soldering and maintenance problems of old fashioned telephone type relays.
2. Symmetrical shape and rugged design provides for minimum mounting space and maximum protection to moving parts when handling.
3. Armature contacts consist of two silver alloy wires per pole providing highly reliable redundant contact surfaces.
4. With plug-in connectors "A", relay contacts can be "programmed" to suit specific circuit requirements.
5. Special hardware available allowing for mating terminal block assembly and easy mounting on chassis or rack.
6. The Type 81 relay can be easily assembled in groups, simplifying wiring and ease of programming. Requires minimum rack or chassis space.

TYPE 81 SPECIFICATIONS

Contact Form	4 PDT
Contact Rating	3 amp. (carry only)*
Contact Material (Std.)	Eutectic Alloy—Silver-Copper
Operating time (Nom.)	5.5 milliseconds max. inc. bounce
Life	200 million operations
Coil Form	Single or Double Winding (Pic & Hold)
Coil Voltage	20 volts D.C. thru 115 volts D.C.
Coil Power	4 watts max.
Breakdown Voltage	1250 volts RMS 60 cycle to frame
Ambient Temperature	50° C
Weight	Approximately 1 1/4 oz.
Overall dim. (Approx.)	Including plug—2 1/4" x 1/2" x 2"

*Consult Factory for Ratings for Making and Breaking Loads.

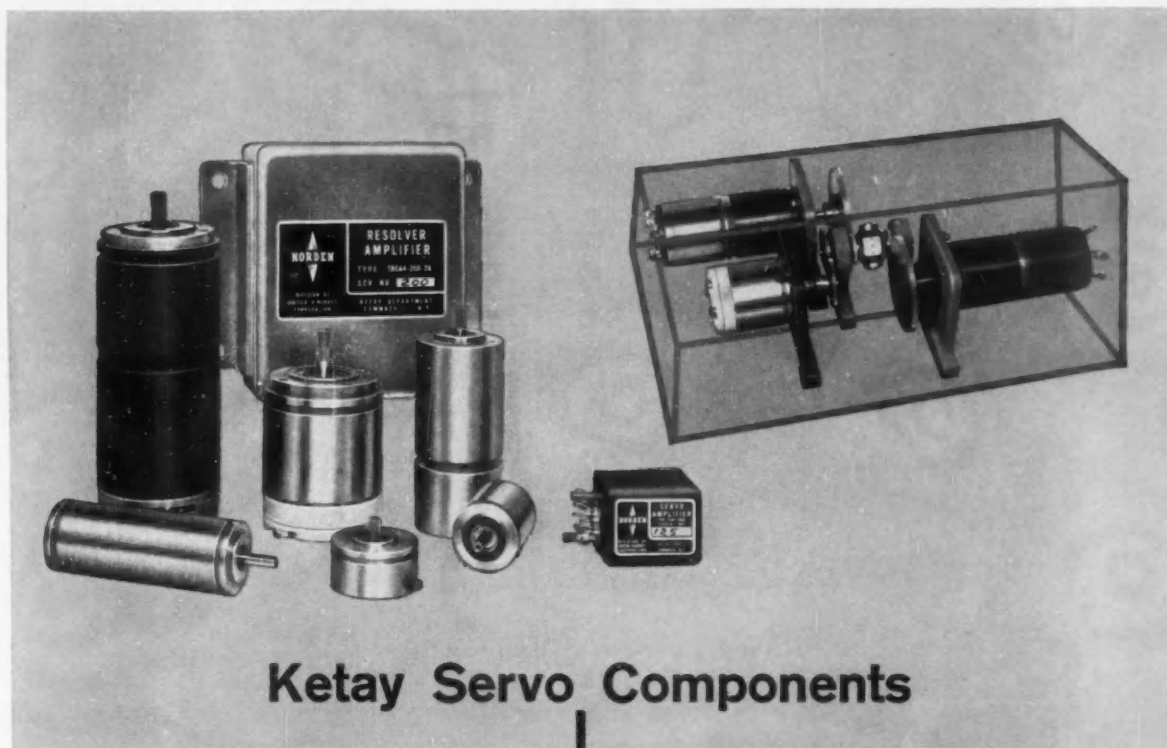


Consult Your Local RBM Product Application Engineer or Write for Bulletin 2000



RBM Controls Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA
Factories Located at North Manchester and Logansport, Indiana



Ketay Servo Components

available separately... or in modular packages

Ketay servo components are recognized throughout industry and military agencies for outstanding accuracy and reliability. The advanced designs and quality control techniques provide precision to satisfy the most exacting requirements of today's servo systems.

Now this same high reliability is available to your servo systems with Ketay modular packages. These packages are produced with the identical quality control procedures as are the individual components... and provide your servo systems with the maximum accuracy of the individual components.

Here are a representative group of Ketay components available separately or packaged in combination.

SYNCHROS. Control and torque transformers; transmitters and receivers; torque and control differential transmitters to MIL-S-20708A. Sizes 05 to 31.

SERVO MOTORS. Featuring high ratio of stall torque to power input at maximum rpm. A wide variety in frame sizes from 05 to 23. Exceed environmental requirements of MIL-E-5272A.

AMPLIFIERS. Complete range of servo amplifiers, transistorized and magnetic. Outputs from 1.5 to 9 watts, designed to operate in ambients from -55° to $+125^{\circ}\text{C}$. Also dual channel resolver amplifiers.

POTENTIOMETERS. A wide choice of types including single-turn and multi-turn, with linear and non-linear windings, ganged potentiometers as well as sector and pendulum pots. High temperature (to 300°C) and nuclear resistant models.

RESOLVERS. Size 08 to 23 resolvers available offering functional accuracies to .03%, stability over a range of -55°C to $+125^{\circ}\text{C}$, high input impedance. Vernier resolvers available with null spacing accuracy of 10 seconds.

FLOATED RATE GYROS. Variety of gyro spin motor and pick-off characteristics may be combined to fulfill desired specifications.

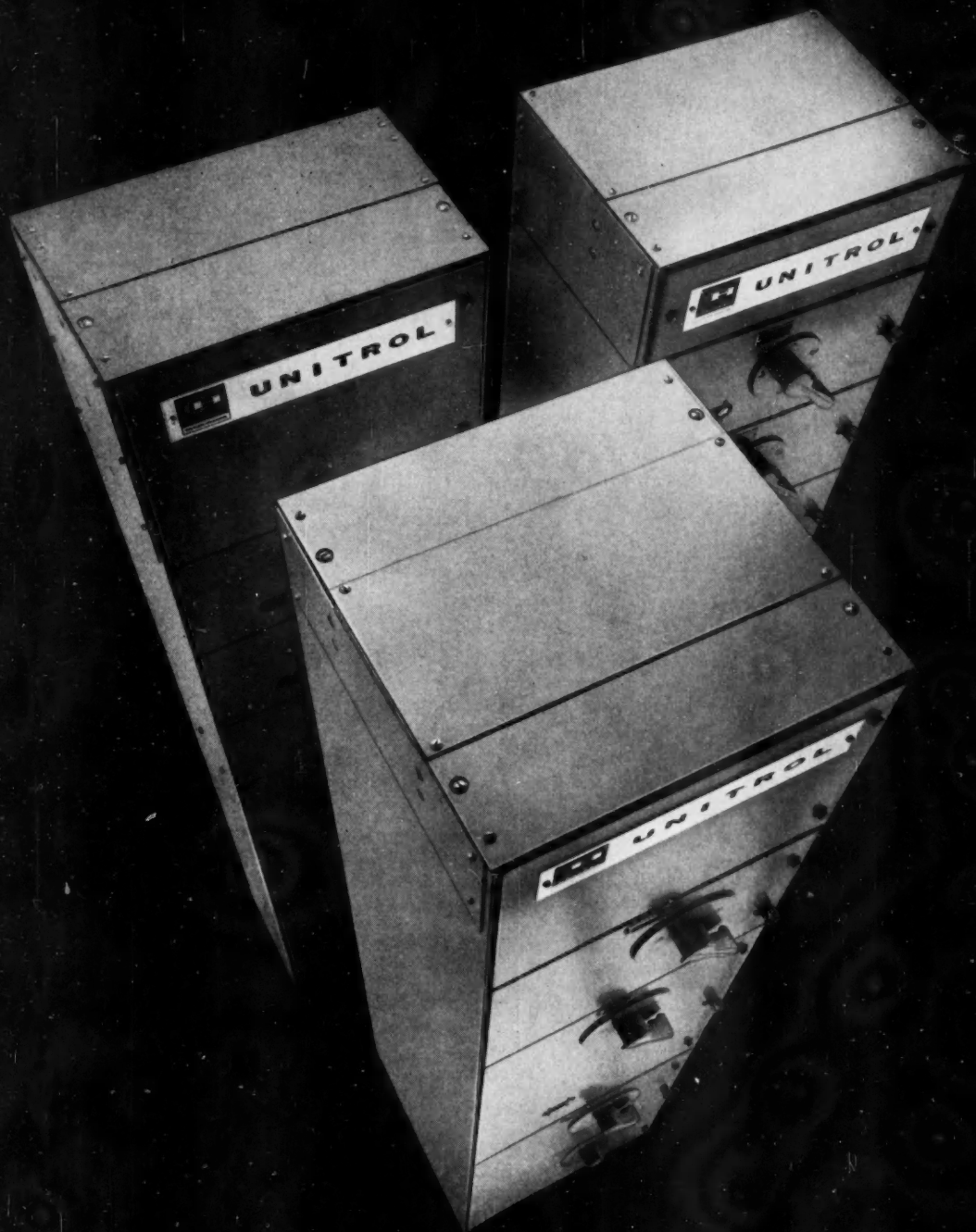
MOTOR TACHOMETERS. Integrating and damping types. Size 15 integrating model requires no warm-up time, meets environmental requirements of MIL-S-17806. Size range from 08 to 18.

Ketay manufactures a precision line of rotating components and encoders in a wide range of sizes to meet your specific requirements.



**UNITED AIRCRAFT CORPORATION
NORDEN DIVISION**

KETAY DEPARTMENT, COMMACK, LONG ISLAND, NEW YORK



WHO ELSE BUT CUTLER-HAMMER GIVES YOU ALL THESE FEATURES?

- | | | |
|----------------------------------|---------------------------------|------------------------------------|
| ■ Quick and safe maintenance | ■ Add options . . . no crowding | ■ 100% interchangeability |
| ■ All front connections. | ■ Vertical bus silver plated | ■ Positive off-power test position |
| ■ Tough baked enamel finish | ■ Quick latch door fasteners | ■ Modular construction |
| ■ Completely safe wiring troughs | ■ Five padlock locations | |



Now! Cutler-Hammer Unitrol in two new shallow depths!

*Get more compactness, more flexibility in motor control
centers plus Cutler-Hammer dependability and safety*

With Unitrol, you eliminate the high cost of mounting and wiring individual starters, as well as using far less space. Unitrol gives you flexibility, too . . . easy to change starters to fit needs and expand without disturbing other starter units. The two new shallow depths (15" and 12") make Unitrol practical even on catwalks or tunnels. Unitrol's modular design lets you put as many as 8 Size 1 starters in a single section and still leave room for many options.

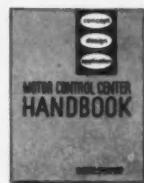
But, probably more important is the safety factor built into Unitrol—safety for the men and machines. For instance, you can *lock* each unit in maintenance position for complete safety. Look at the features at the left for some of the extra values in Unitrol.

What's new at Cutler-Hammer?

You can see the new spirit and vitality in a flood of new products and product improvements. Plant capacity has been increased. We've added new engineering talent to increase efficiency. Everywhere you look, you can see that we're ready to help you meet the challenge of the years ahead. Get the inside story from the Cutler-Hammer sales office nearest you.

NEW! FREE! BOOKLET:

The "Motor Control Center Handbook" gives you practical facts on selecting the proper control as well as estimating for future needs. Send for Pub. LJ-1 G227 now!



WHAT'S NEW? ASK...

CUTLER-HAMMER

Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. • Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.



Solve Multi-Point Temperature Control Problems...

*at 2/3 cost of
competitive systems*

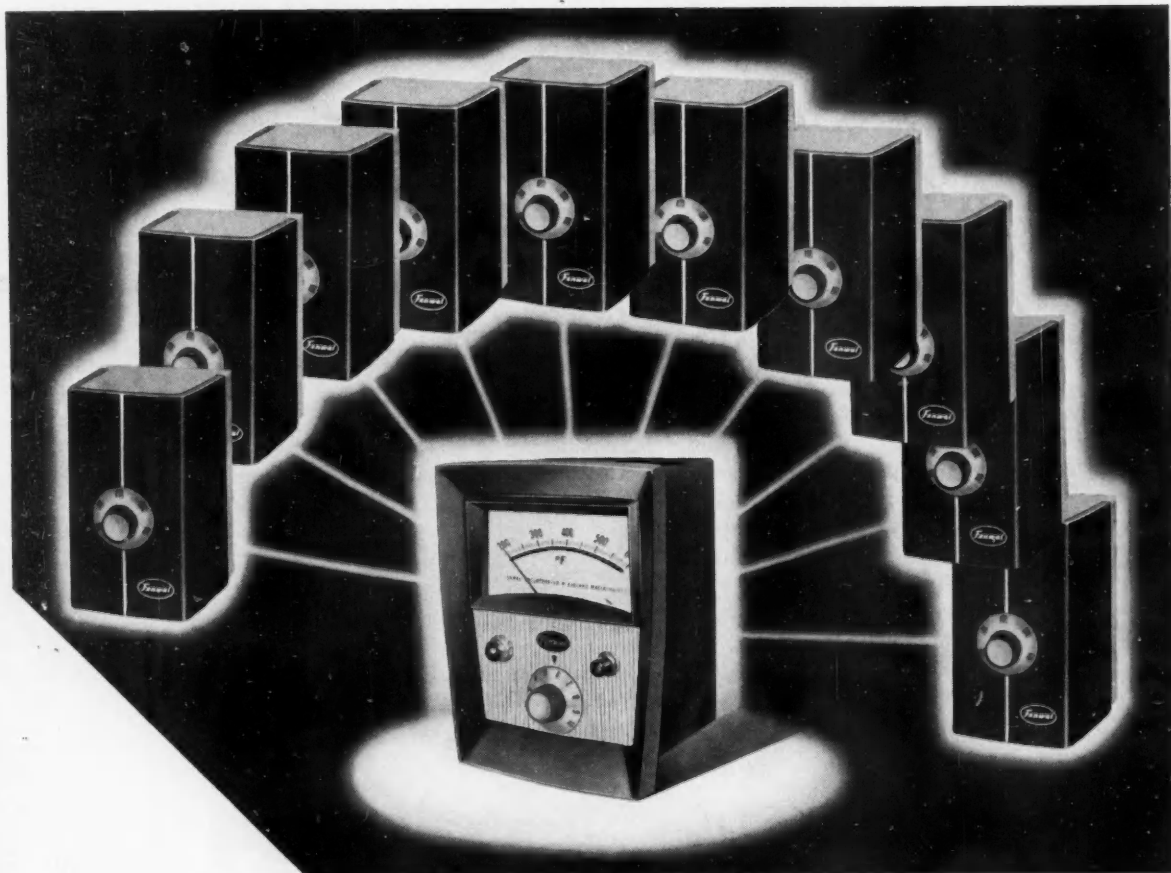
You get them all — wide ranging versatility . . . maximum sensitivity . . . easy installation and servicing! These features *combine* in a Fenwal 536-580 multi-point monitoring system to give you precise, transistorized temperature control and indication. And *you choose the features you need to suit your own requirements!*

Examine these cost saving advantages: Indication and control circuits are separate . . . the 536-580 system eliminates the need for separate indication and control at each point. You can build a control system concurrent with your needs — start with 2 points and build up to 10 points without paying a premium at the outset. The complete control system is built from *standard* catalog parts, thereby eliminating the need to buy costly "specials" for servicing at a later date.

Individual points can have either proportioning or ON/OFF control modes. The system permits "flick of switch" indication of from 2 to 10 temperatures. Individual set points can be adjusted from a central control panel or through a separate potentiometer remotely located. You select your own number of points and you *pay only for the options you use.*

Choose from five standard temperature ranges — from -50 to 600°F . . . expanded scales permit fine temperature adjustments and improved readability, and *the entire system gives you sensitivity to within 0.1°F.*

Both instruments are smartly styled to perfectly complement modern industrial machines and interiors. A Fenwal engineer will be glad to supply information on this system, or any other temperature control in Fenwal's broad line. Write Fenwal Incorporated, 294 Pleasant Street, Ashland, Mass.



Another
example of how

Fenwal

CONTROLS TEMPERATURE . . . PRECISELY

a new line of
Bulletin 709 motor starters by
ALLEN-BRADLEY

- smaller size
- greater interrupting capacity
- even more millions of trouble free operations
- more wiring room
- elegant styling
- A-B "quality" throughout



*A "family" of
7 starter sizes
... each one
entirely new*

greatest advance in motor control in 30 years



In appearance... in performance... in physical size and weight... these Allen-Bradley Bulletin 709 solenoid starters are *completely new in every way!*

NEW COMPACTNESS. Size reductions are so drastic you'll hardly believe your eyes. The tables below will give you some idea of how the new line of Bulletin 709 starters compares with the old.

A TREMENDOUS INCREASE IN LIFE—both mechanical and electrical. All of these new starters are good for many more millions of trouble free operations.

NEW PATENTED MAGNET. For its weight and size, the most powerful magnet used on motor control. Its short, cushioned stroke assures long contact life. A new, permanent air gap prevents any possibility of magnetic sticking. "Snap action" guarantees positive contact opening and closing.

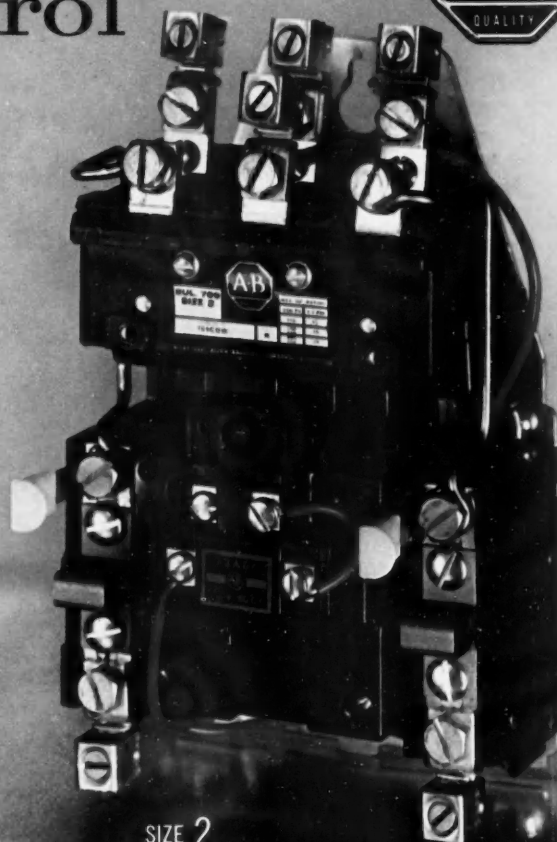
NEW MOLDED COIL. Impervious to atmospheres that could cause trouble, and also protected against mechanical damage. All coils are easily removed—from the front of the starter.

NEW CONTACTS. New double break contacts of cadmium oxide silver resist welding... close and seat firmly without sliding or wear-causing motion.

NEW OVERLOAD RELAYS. Not only "trip-free" but also "tamperproof," to reliably protect motor and machines. Of course the new relays were designed to use the old Bulletin 709 heating elements which you have in stock.

NEW ENCLOSURES. Completely restyled by Brooks Stevens—and so modern. They are a sales asset on any type of modern machine or industrial installation.

BETTER WRITE FOR MORE INFORMATION ON THIS
REVOLUTIONARY NEW BULLETIN 709 STARTER!



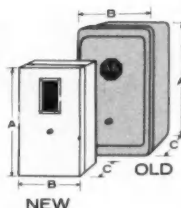
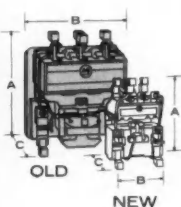
SIZE 2

New Bulletin 709 Solenoid Motor Starter

CHECK THE "NEW" WITH THE "OLD" BULLETIN 709 DIMENSIONS

The wiring room in the new enclosures will delight the electrician.

Starter Size	OPEN TYPE STARTERS					
	NEW			OLD		
	Height A	Width B	Depth C	Height A	Width B	Depth C
00	3 $\frac{5}{8}$	3 $\frac{7}{8}$	3 $\frac{1}{4}$	—	—	—
0	5 $\frac{7}{8}$	4 $\frac{1}{4}$	3 $\frac{1}{2}$	5 $\frac{5}{8}$	4 $\frac{3}{4}$	3 $\frac{1}{4}$
1	6 $\frac{5}{8}$	4 $\frac{1}{2}$	3 $\frac{1}{2}$	5 $\frac{5}{8}$	5	3 $\frac{1}{4}$
2	7 $\frac{3}{4}$	4 $\frac{5}{8}$	3 $\frac{1}{2}$	10 $\frac{1}{4}$	5 $\frac{3}{4}$	4 $\frac{3}{4}$
3	10 $\frac{1}{4}$	6 $\frac{1}{4}$	5 $\frac{1}{2}$	12 $\frac{3}{4}$	7 $\frac{1}{4}$	5 $\frac{1}{2}$
4	11 $\frac{1}{4}$	7 $\frac{1}{4}$	6 $\frac{1}{4}$	16 $\frac{1}{4}$	12 $\frac{3}{4}$	6 $\frac{1}{4}$
5	14 $\frac{1}{4}$	9	6 $\frac{1}{2}$	20	16 $\frac{3}{4}$	8 $\frac{3}{4}$



Starter Size	NEMA 1 ENCLOSURES					
	NEW			OLD		
	Height A	Width B	Depth C	Height A	Width B	Depth C
00	7 $\frac{5}{8}$	4 $\frac{7}{8}$	4 $\frac{1}{4}$	—	—	—
0	9 $\frac{1}{8}$	6 $\frac{1}{4}$	4 $\frac{3}{8}$	7 $\frac{7}{8}$	5 $\frac{3}{4}$	4 $\frac{1}{4}$
1	10	6 $\frac{1}{2}$	4 $\frac{3}{8}$	8 $\frac{1}{4}$	6 $\frac{3}{4}$	4 $\frac{1}{4}$
2	12	7 $\frac{3}{8}$	4 $\frac{3}{8}$	14 $\frac{1}{2}$	9	5 $\frac{1}{4}$
3	16 $\frac{3}{8}$	10 $\frac{3}{8}$	7	19 $\frac{1}{2}$	11 $\frac{3}{4}$	6 $\frac{1}{4}$
4	22	11 $\frac{3}{8}$	8	26 $\frac{3}{8}$	14 $\frac{3}{4}$	7 $\frac{1}{4}$
5	32 $\frac{1}{4}$	17 $\frac{3}{8}$	9 $\frac{3}{8}$	41 $\frac{1}{2}$	19 $\frac{3}{4}$	13 $\frac{3}{4}$

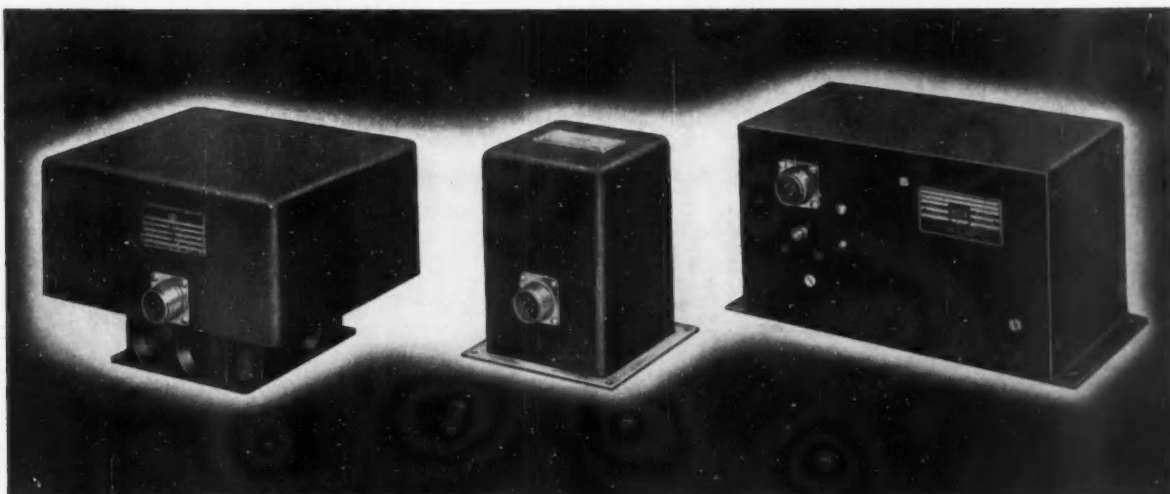
B-61-RM

ALLEN-BRADLEY

Member of NEMA

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wisconsin

*Quality
Motor Control*



Where can you use solid-state inverters with performance like this?

- **Wide operating temperature ranges**—Models now available and in development, designed for ambients ranging from a low of -55°C to $+125^{\circ}\text{C}$.
- **Closer frequency regulation**—As close as ± 0.02 cps under full load at ambients from $+60^{\circ}\text{F}$ to 175°F in some models.
- **Voltage regulation to $\pm 0.87\%$** under full load at ambients ranging from -20°F to $+175^{\circ}\text{F}$.
- **High-power-conversion efficiencies** under full load 28v dc input.
- **Protection against output overloads**—100 va models will withstand 100 va overloading, for 10 minute periods once an hour.
- **Transient voltage suppression**—Transient suppressor removes or attenuates voltage spikes—safeguards semi-conductor elements.

The inverters listed here are only a small portion of the Hamilton Standard line of power conversion equipment. Other models are available to satisfy a wide range of industrial power supply problems . . . microwave and telemetry systems . . . remote signalling, warning, and measurement systems—wherever circuit interruption cannot be tolerated.

Whatever your power conversion requirements are, Hamilton Standard engineering can be of real help to you now . . . in the initial planning or redesign stage.

CHARACTERISTICS OF 100-VA STATIC INVERTERS

CATALOG NO.	ECB-1.1-AA	ECB-1.1.7-AA	ECB-1.1.13-AA
Output			
Voltage	$115\text{v} \pm 1\text{v}$	$115\text{v} \pm 5\%$	$115\text{v} \pm 5\text{v}$
Frequency	$400 \pm \frac{1}{4}$ cps	$400 \text{ cps} \pm 1\%$	$400 \pm 1\%$
Phases	Three	Three	Single
Transient protection	Yes	Yes	Yes
Input voltage			
Nominal	28v dc	28v dc	28v dc
Range	18-29v dc	20-29v dc	18-29v dc
Dimensions	5"x6"x8 $\frac{3}{4}$ "	5"x6"x7 $\frac{3}{8}$ "	5 $\frac{1}{8}$ "x5 $\frac{1}{8}$ "x8 $\frac{3}{8}$ "

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GUIDE**

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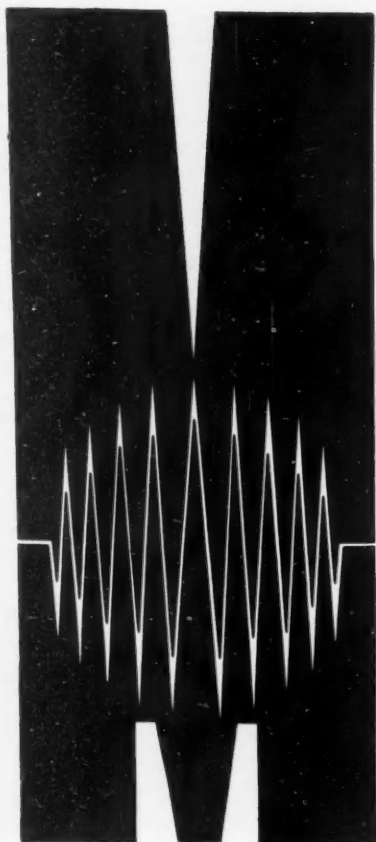
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Company

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UNITED AIRCRAFT CORPORATION
HAMILTON STANDARD DIVISION
ELECTRONICS



PARIS FROM MAY 9TH TO MAY 17TH 1961

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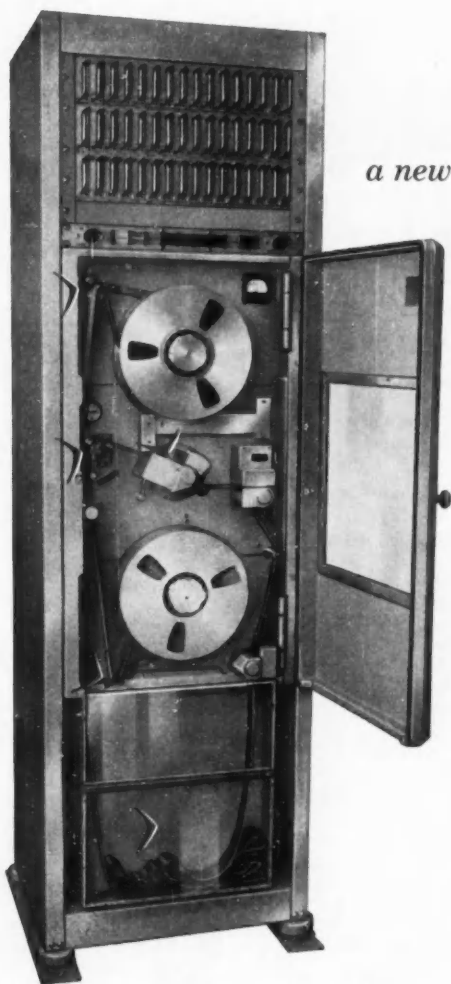
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Tél. BALZAC 77-50

FRANCE for the complete documentation, stating if you want it in French, German or English.



a new concept in tape handling

SANGAMO 460-SERIES MAGNETIC TAPE INSTRUMENTATION

Now, one recorder/reproducer—the Sangamo 460-Series can be changed instantly from reel to loop operation without rehandling the tape or making any changes in the transport. It can be programmed for reels only, reels and basket, or basket only simply by means of a selector switch. It will handle up to 2-inch wide tape. Other standard tape widths can be utilized by changing head and guides. The Sangamo 460-Series is a fully transistorized magnetic tape recorder/reproducer for application in direct analog, wide band, FM, PDM, and PCM instrumentation systems.

The tape is threaded from feed reel to take-up reel through the storage basket. Data can be recorded while up to 250 feet of tape is fed directly into the basket. After recording, the tape can be cut, and spliced for immediate data reproduction in loop operation. Where pre-recorded tapes are to be played back, and the data is contained on a relatively short length of tape, the same unique transfer from reel to loop operation is possible. The Series-460 feed and takeup reel servos operate with a tape tension between 6 and 8 ounces. Additional tension necessary to insure continuous head-tape contact is provided by a vacuum pad which also cleans the tape before it passes the head. In turn, the head is mounted almost in contact with the drive capstan. This results in a very short span of tape that requires precise positioning. Differential flutter and weave is reduced to the point where inter-channel time displacement error between outside tracks on one inch wide tape is less than ± 2.0 microseconds at 60 IPS.

The 460-Series has exclusive wide-range, fast-response, Hare Tape Synchronized servo speed control. This control reduces instantaneous and long-term record-playback speed deviations to a level several times lower than other speed control systems. You get magnetic tape instrumentation system accuracies heretofore considered unattainable.

The tape transport and fourteen (14) tracks of Record/Reproduce electronics are contained in a single standard 19" W x 71" H cabinet. This unusual compactness is achieved through transistorized electronic circuitry. The solid state circuitry means greater reliability, reduced weight, lower heat dissipation, and lower power consumption.

For the name of the technically qualified Sangamo representative nearest you, and for complete details on the Sangamo 460-Series, please write for Bulletin 3400.

SANGAMO 460-SERIES PERFORMANCE and CHARACTERISTICS

Start Time: 1.0 second to synchronism @ 60 ips with servo speed control and 1" wide tape.

Stop Time: 0.2 seconds from 60 ips.

Instantaneous Time Displacement Error: Less than 25.0 microseconds (including flutter) @ 60 ips.

Long Term Time Displacement Error: $\pm 0.01\%$ standard. Higher accuracies available.

Interchannel Time Displacement Error: ± 2.0 microseconds @ 60 ips between outside tracks on 1" tape.

Servo Speed Control Range: $\pm 15\%$ nominal tape speed.

Servo Speed Control Response: $\pm 15\%$ speed change per second.

Tape Widths: Standard sizes from $\frac{1}{4}$ to 2".

Reel Sizes: 14" or smaller.

Mounting: 1 standard 19" equipment rack for a complete 14 track record/reproduce system with power supplies and servo speed control.

Power Requirements: 117 volts, 60 cps $\pm 10\%$ single phase. All D C drives. 7.0 amperes load for 14 track system.

Weight: Approximately 500 pounds for 14 track system.



SANGAMO ELECTRIC COMPANY

SPRINGFIELD, ILLINOIS

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APRIL 1961

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75



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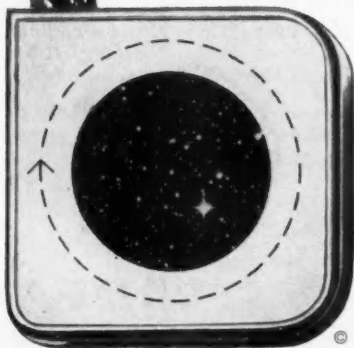
Beckman Systems... a world-famous name that stands for the most advanced developments in Electronic Data Processing. Beckman research, study and engineering groups were the first to develop many of today's realistic answers to the ever-increasing demands for reliable, high performance data processing systems. Among them... Multiple Channel Recording, High-Speed Digital Processing, Solid-State Circuitry, and Floating, Low-Level Amplification. Systems applications include space vehicle guidance, automatic plant control, missile ground support and nuclear research.

At Beckman, the difficult problems are our business. Here, the selection of qualified engineers and scientists is as equally important as the problem at hand. In an atmosphere where initiative is encouraged and where achievement is well recognized, top men in the field are your associates in meeting the challenges of tomorrow. Both you and your family will heartily endorse Southern California living. World-renowned Disneyland, beach communities, desert resorts, and mountain areas all are minutes away.

If you have a background in Systems Management, Telemetry, Timing and Translation, Research and Study, Systems Engineering, or Advanced Circuits Development, why not contact Mr. James R. Abell. He will arrange for an interview in your area to discuss opportunities with Beckman Systems in Northern or Southern California.

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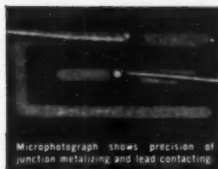


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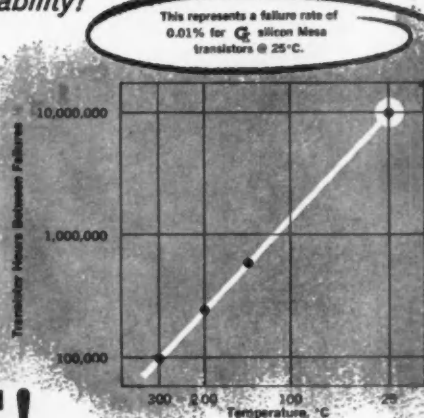
General Instrument Semiconductor... Leader in Reliability!

G ANNOUNCES INDUSTRY'S MOST RELIABLE SILICON MESA TRANSISTORS!

General Instrument Semiconductor has achieved a major breakthrough in transistor manufacture! Through detailed research, careful product development and advanced production techniques we offer the most reliable silicon mesa transistors available today!



Microphotograph shows precision of junction metalizing and lead contacting



PROOF! Extended life tests at each of temperatures shown above, demonstrate G superior mesa performance with 0.01% per 1000-hrs. failure rate at 25°C.

Exclusive combination of reliability benefits offered by G through long-term R & D:

- Advanced techniques of junction metalizing;
- Superior junction contacting;
- Permanent surface passivation;
- 100% lot stabilization with 96-hour bake at 300°C; and
- Critical analysis with automatic equipment for exhaustive parameter testing.

COMPLETE LINE OF G SILICON MESAS...FROM STOCK

What are your needs? General Instrument offers a full line of double diffused NPN silicon mesas for your most exacting applications. Abbreviated ratings and characteristics below indicate a wide range of usefulness: Very high speed saturated switching; VHF tuned amplifiers; and units with high beta linearity for magnetic memory drivers

and video amplifiers.

Available in accordance with MIL-S-19500/99A (G 2N696, 2N697) and MIL-S-19500/120 (G 2N706). Contact General Instrument today for more information on these realistically-priced units, and the name of your local authorized stocking distributor.

GENERAL INSTRUMENT NPN SILICON MESA TRANSISTORS										
Type	Case	RATINGS			CHARACTERISTICS					
		V_{CE0}	V_{BE0}	Maximum Dissipation ($T_{case} = 25^\circ C$)	I_{C0}	I_{B0} $V_{CE} = 10\text{ v}$ $I_C = 150\text{ ma}$ pulsed	I_{B0} $V_{CE} = 10\text{ v}$ $I_C = 50\text{ ma}$ $f = 20\text{ Mc}$	V_{CE} $I_B = 15\text{ ma}$ $I_C = 150\text{ ma}$	V_{CE} (SAT.) $I_B = 15\text{ ma}$ $I_C = 150\text{ ma}$	C_{ob} $I_B = 0$ $V_{CE} = 10\text{ v}$
2N696	TO-5	60 v	5 v	2 watts	$V_{CE} = 30\text{ v}$ $T = 25^\circ C$ Ambient: $1\text{ }\mu\text{a}$ max $T = 150^\circ C$ Ambient: $100\text{ }\mu\text{a}$ max	20 min 60 max	2 min	1.3 v max	1.5 v max	35 pf max
2N697	TO-5	60 v	5 v	2 watts	$V_{CE} = 30\text{ v}$ $T = 25^\circ C$ Ambient: $1\text{ }\mu\text{a}$ max $T = 150^\circ C$ Ambient: $100\text{ }\mu\text{a}$ max	40 min 120 max	2.5 min	1.3 v max	1.5 v max	35 pf max
2N699	TO-5	120 v	5 v	2 watts	$V_{CE} = 60\text{ v}$ $T = 25^\circ C$ Ambient: $2\text{ }\mu\text{a}$ max $T = 150^\circ C$ Ambient: $200\text{ }\mu\text{a}$ max	40 min 120 max	2.5 min	1.3 v max	5.0 v max	20 pf max
2N706	TO-18	25 v	3 v	1 watt	$V_{CE} = 15\text{ v}$ $T = 25^\circ C$ Ambient: $0.5\text{ }\mu\text{a}$ max $T = 150^\circ C$ Ambient: $30\text{ }\mu\text{a}$ max	$V_{CE} = 1\text{ v}$ $I_C = 10\text{ ma}$ 15 min	$V_{CE} = 15\text{ v}$ $I_C = 10\text{ ma}$ $f = 100\text{ Mc}$ 2 min	$I_B = 1\text{ ma}$ $I_C = 10\text{ ma}$ 0.9 v max	$I_B = 1\text{ ma}$ $I_C = 10\text{ ma}$ 0.6 v max	6 pf max
2N1252	TO-5	30 v	5 v	2 watts	$V_{CE} = 20\text{ v}$ $T = 25^\circ C$ Ambient: $10\text{ }\mu\text{a}$ max $T = 150^\circ C$ Ambient: $600\text{ }\mu\text{a}$ max	15 min 45 max	2 min	1.3 v max	1.5 v max	45 pf max
2N1253	TO-5	30 v	5 v	2 watts	$V_{CE} = 20\text{ v}$ $T = 25^\circ C$ Ambient: $10\text{ }\mu\text{a}$ max $T = 150^\circ C$ Ambient: $600\text{ }\mu\text{a}$ max	30 min 90 max	2.5 min	1.3 v max	1.5 v max	45 pf max
2N1420	TO-5	60 v	5 v	2 watts	$V_{CE} = 30\text{ v}$ $T = 25^\circ C$ Ambient: $1.0\text{ }\mu\text{a}$ max $T = 150^\circ C$ Ambient: $100\text{ }\mu\text{a}$ max	100 min 300 max	2.5 min	1.3 v max	1.5 v max	35 pf max



GENERAL INSTRUMENT
GENERAL TRANSISTOR



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Whatever you need a data printer for, Clary has a proven model to do the job

*At Clary you'll find the world's largest selection
of solenoid actuated digital data printers.*

These include Parallel Entry Printers, Printing Timers,
Time-Data Printers, and Serial Entry Printers. All are reliable,
proven printers... printers whose simple circuitry, low cost,
small size, desk top mounting, and modern design have made
them the most "asked for" printers in the world.

*Clary Printers are now being used
in the following applications:*

*Automatic Checkout Systems
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Logging of Time and Origin of Alarm Signals
Automatic Engineering Data Recording
By-Product Accumulation of Office Machine Operations
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ELECTRONICS DIVISION
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*Manufacturer of output printers, computers, electronic data-handling
equipment, aircraft and missile components.*



There's **1** source for

2 way

3 way

or **4** way **MIDGET SOLENOID VALVES**

SHOWN $\frac{1}{4}$ ACTUAL SIZE



Progressive designers, the men who lead the trend toward miniaturization, depend on ASCO as the one source for a full line of midget solenoid valves. The unexcelled quality and dependability that ASCO pioneered in the solenoid valve field is found, too, in today's midget solenoid valves. Only the size has been reduced.

For flow applications using air, gas, water, light oil, refrigerants and many other liquids, ASCO Midget Valves assure complete safety and truly exceptional performance.

ASCO Midget Solenoid Valves are available with standard, watertight or explosion-proof enclosures. Pipe sizes $\frac{1}{8}$ " and $\frac{1}{4}$ "; pressure range 0-1000 psi.

There's *one* source that solves virtually any solenoid valve problem—ASCO. Write today for complete data on ASCO Midget Solenoid Valves—or outline any of your requirements. We'll be pleased to assist you.

ASCO Valves

Automatic Switch Co. 50-G HANOVER RD., FLORHAM PARK, N. J., FRONTIER 7-4600.
AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

ASCO



What is "Pinpoint Recruiting"?

It is the act of going directly to the most concentrated source of supply to find 'the right man' for the job.

Control Engineering is his professional literature. Through its consistently high calibre editorial content, he keeps pace with developments in measurement and control and information systems. The design and application of these are his broadgauge field. His forte is computer engineering and programming, systems analysis, equipment design...the whole range of disciplines contributing to today's most dynamic technology.

Your most direct link to 'the right man' is in the pages of the publication he makes it his business to read.

*Write for the 20-page file-size booklet "How to Attract Engineers"
Address: David Hawksby, Classified Advertising Division,
Control Engineering, Post Office Box 12, New York 36, N. Y.*

The man you need is the man who reads

Control
ENGINEERING
INSTRUMENTATION AND CONTROL SYSTEMS

Measure and record DC current, 0.1 ma to 10 amps without breaking leads, without circuit loading!



New 428B Clip-on DC Milliammeter with recorder output!

Now you can measure and record dc current to 10 amps without interrupting the circuit and with no circuit loading. You simply slip the jaws of the 428B probe around a bare or insulated wire and read dc, even in the presence of equally strong ac on the same wire. No need to break leads. The 428B reads dc current directly in 9 ranges by sensing the magnetic flux induced by dc current in the wire.

To measure current difference between two separate wires just clip the probe around them both and read, then reverse one lead and read their sum! For even greater sensitivity you simply increase the number of lead loops through the probe, increasing sensitivity by the same factor as the number of loops.

The recorder/oscilloscope output, dc to 300 cps, makes it easy to record dc levels as well as analyze ground buss, hum and ripple currents on an oscilloscope—all without circuit loading.

HP also offers Model 428A Clip-on DC Milliammeter. This instrument is similar to 428B except that coverage is limited to 3 ma to 1 ampere (6 ranges), the recorder output is not included, and price is somewhat lower.

HEWLETT-PACKARD COMPANY

1066H Page Mill Road Palo Alto, California, U.S.A.
Cable "HEWPACK" Davenport 6-7000

Sales representatives in all principal areas

SPECIFICATIONS

Current Range: 428A, 3 ma to 1 a full scale in 6 ranges
428B, 1 ma to 10 a full scale in 9 ranges

Accuracy: $\pm 3\%$, ± 0.1 ma

Probe Inductance: < 0.5 uh introduced into measured circuit

Probe Induced Voltage: < 15 mv peak into measured circuit

AC Rejection: AC with peak value less than full scale affects meter accuracy less than 2% at frequencies above 5 cps and different from carrier (40 KC) and its harmonics. (On 428B 10 amperes range, ac is limited to 4 amperes peak)

Recorder/Oscillator Output: 428B, approximately 1.4 v across 1,400 ohms full scale. Frequency response dc to 300 cps

Probe Insulation: 300 v maximum

Probe Tip: $\frac{1}{2}$ " x $\frac{9}{32}$ ". Aperture diam. $\frac{3}{16}$ "

Size: Cabinet, $7\frac{1}{2}$ " x $11\frac{1}{2}$ " x $14\frac{1}{4}$ "; rack mount, 19" x 7" x 13" behind panel

Weight: Cabinet, 19 lbs; rack mount, 24 lbs.

Price: 428A, \$500.00 (cabinet); 428AR, \$505.00 (rack mount)
428B, \$550.00 (cabinet); 428BR, \$555.00 (rack mount)



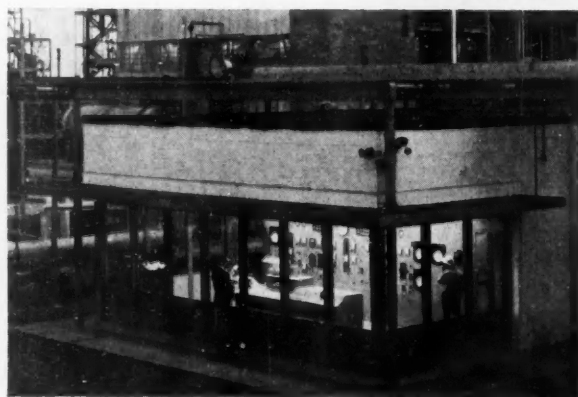
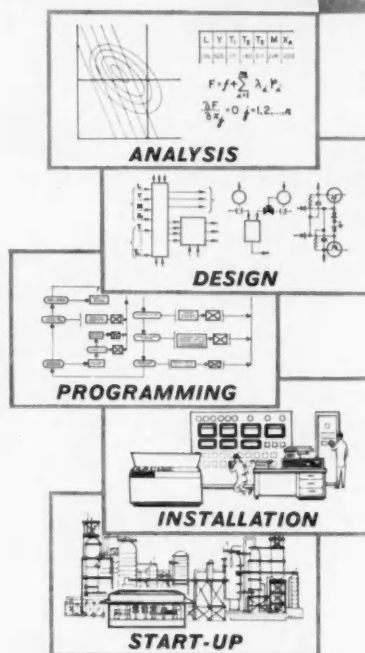
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7058

TOTAL ABILITY IN COMPUTER CONTROL

TOTAL ability in computer control means proven capability in process analysis, system design, control programming, equipment installation and system start-up. TRW Computers Company has this proven capability plus field-proved equipment. In process control and related applications, RW-300 Digital Control Computers have operated more than 200,000 hours with reliability better than 99 percent.



Pictured at the left is a control room of the B. F. Goodrich Chemical Company plant at Calvert City, Kentucky. An RW-300 has been in control of vinyl chloride production at this plant since early in 1960.

This application and other applications in the petroleum, chemical, and power industries are described in a brochure summarizing the experience of TRW Computers Company. To obtain a copy of the brochure, write to any of the offices listed below.

TRW Computers Company

a division of **Thompson Ramo Wooldridge Inc.**

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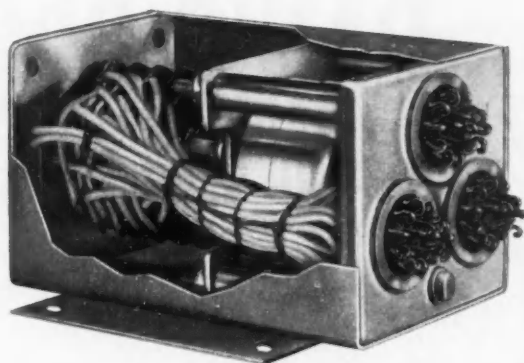


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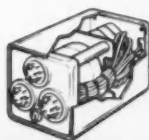
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Beverly Hills • California



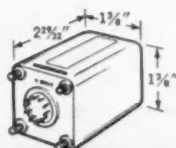
Ledex

Hermetically Sealed Rotary Switch

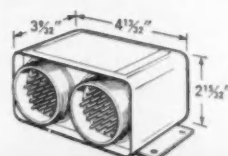
BASIC INFORMATION



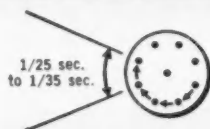
Hermetically sealed switches are permanently protected from moisture, dust, fungus, corrosion and tampering.



Small size 2E Circuit Selector can provide a 1-pole 12-throw, 2-pole 6-throw or 3-pole 4-throw. Weight 3 1/2 oz.



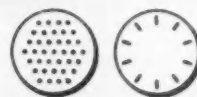
Larger size 3 Circuit Selector is available in many combinations, as 22-pole 2-throw, 12-pole 4-throw, 8-pole 12-throw.



Selectors will step in any pre-selected position at 25 to 35 steps per second.

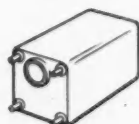


Wiping-type contacts are self-cleaning, reduce fire problems of "dry" circuits. Shorting or non-shorting contacts.

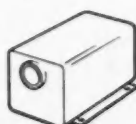


AN Connector Solder Header

Any standard commercial connector can be used.

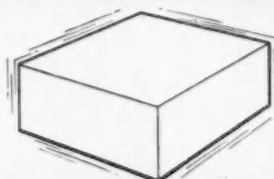


Stud

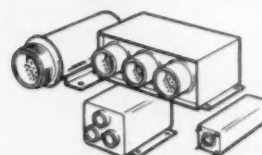


Plate

Switch housings come with stud or plate mounting. Specials on request.



Sealed units to meet missile-age vibration and shock requirements.



Wide selection of stepping switches as well as circuit selectors available in protective housings.

Hermetically Sealed Circuit Selectors and Stepping Switches contain an atmosphere of dry nitrogen which provides a permanent environment for the operation of the switch. They are designed to meet MIL-E-5272A, and will withstand extreme moisture and high altitude conditions in military and industrial installations. Sealed Switches are available in various wire sizes for operation from 6 to 350 VDC. Self-contained plug-in types allow rapid field installation. More than 3000 standard designs are shown in Bulletin D-460.

Other Ledex products include Rotary



Solenoid, Synchromental Stepping Motor, Digimotor Stepping Motor and Indexing Device, Rotary Solenoid Selector Switch, Digimotor Selector Switch.

Switching applications include circuit selecting, stepping, counting, programming and sequencing.

Mechanical applications of other Ledex products include actuation of valves, vanes, printers, shafts. Write for literature, mentioning application, to Ledex Inc., Dayton 2, Ohio; Marsland Engineering, Ltd., Kitchener, Ont.; NSF Ltd., 31 Alfred Place, London, Eng.; NSF GmbH, Nurnberg, Germany.

SPLIT-SECOND CONTROL

0.000000 sec.

Critical controlled variable exceeds established limits

0.000001 sec.

0 1 2
 μ S μ S μ S

RCA 110 is signalled that trouble has occurred

0.000057 sec.

The 110 interrupts its program to investigate hot spot

0.000337 sec.

Alarm condition is pinpointed and analyzed

0.000617 sec.

All necessary control actions are initiated to bring process back to normal

PANIC-PROOF

RCA 110 Control Computer

When something goes haywire in a process, the RCA 110 Control Computer doesn't panic and take unnecessary or ill-considered control actions. Instead, the RCA 110 has the speed, the capacity and the reliability to handle alarm conditions as if they were normal. It's the *one* control computer that combines "panic-proof" abilities with "panic-proof" design to assure you that it will do the job and stay on the job.

PANIC-PROOF ABILITY

- Real-time speed permits thorough analysis before taking control action.
- Automatic priority analysis provides "first things first" control.
- Input checking ability verifies authenticity of information received.
- Ability to by-pass inoperable peripheral equipment prevents needless loss of control.
- Complete self-checking routines inspect for proper performance at all times.
- Double protection through duplicate program storage in core and drum memories, guarding against program error.
- Automatic power switching to alternate source without loss of control, if main power fails . . . controlled shutdown with all information preserved in event of complete power failure.

PANIC-PROOF DESIGN

- Pressurized heavy-duty cabinets keep system free of damaging atmospheres.
- Optional internal heat exchangers for severe environments.
- Proven circuit designs and circuit boards.
- Drum memory circuits independent of drum speed over wide limits.
- Low impedance grounding path to protect low-level signals.
- Complete parity checking of all information.
- Gradual power turn-on protects against start-up shock.
- Non-volatile drum and core storage to protect memory contents.

For complete information write Electronic Data Processing Division, RADIO CORPORATION OF AMERICA, 21 Strathmore Road, Natick, Mass.



The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

Smaller Panels

WITH SQUARE D

"System-Designed" RELAYS

CLASS 8501
TYPE DO-22

Write for Bulletin D.

Square D Company,
4041 North Richards Street, Milwaukee 12, Wisconsin

• Square D relays are available for both AC and DC systems—with up to 10 contacts—in both electrically and mechanically held forms. Timing relays are also available in AC and DC versions—with timing intervals from 0.2 second to 3 minutes.

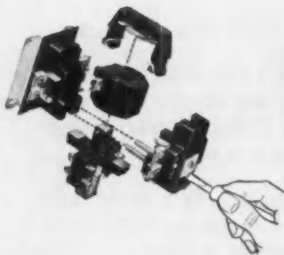
Both relays and timers give you these important advantages:

Require less panel space • Relays are only 3" wide, range in height from 3¼" to 5". Timers are just 2⅝" x 4⅜" or 2½" x 7⅞". Mechanically held relays require no extra panel space.

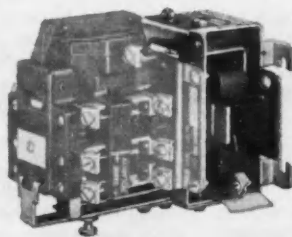
No mounting problems • All Type A timers and Type D relays have identical mounting hole dimensions.

Easy wiring • Choose either pressure wire connectors or slip-on connectors for all terminals.

Long life • Balanced construction reduces wear on single moving part. Epoxy-resin molded coil operates cooler, virtually eliminates coil burnout.



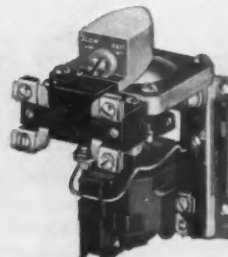
Disassembly from front in 20 seconds makes Square D Type D relays easiest to maintain



Convert any Square D Type D relay to mechanically held with easy-to-use attachment



DC relays have contact arrangements and mounting hole dimensions identical to AC



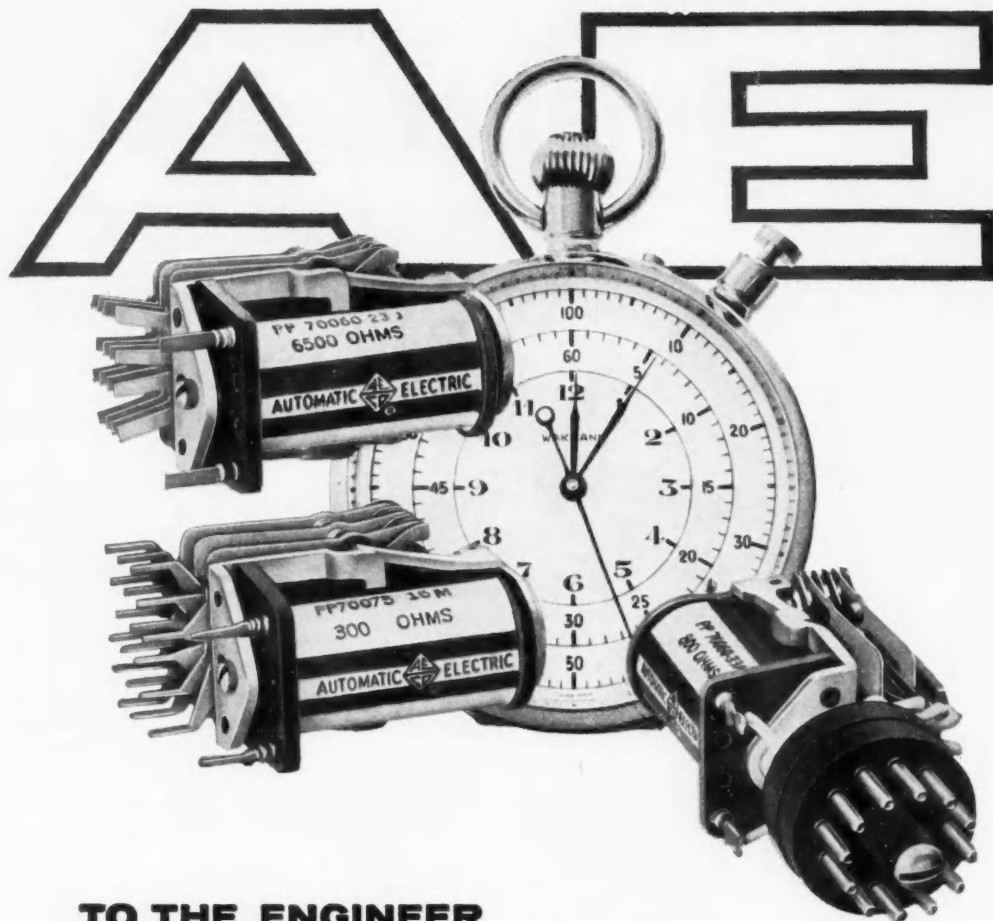
Timing relays convertible from on-delay to off-delay, using only a screwdriver

Square D offers the broadest line of relays, starters and accessories for all types of control systems



SQUARE D COMPANY

WHEREVER ELECTRICITY IS DISTRIBUTED AND CONTROLLED



TO THE ENGINEER looking for a quick connection

Engineers out to cut costs at no expense of reliability can count on dramatic savings in assembly and wiring time by designing around AE Class E relays with quick-connect terminals.

Series EQPC is designed for direct insertion into printed circuits. Series EQTT, with Taper-Tab terminals, provides firm, high-conductivity connections without soldering.

AE also supplies Class E relays prewired for plug-in — with standard 8- to 20-prong octal plugs. Where additional relay protection is essential, the plug-in types are available in hermetically sealed containers or with

dust-tight housings and hold-down brackets.

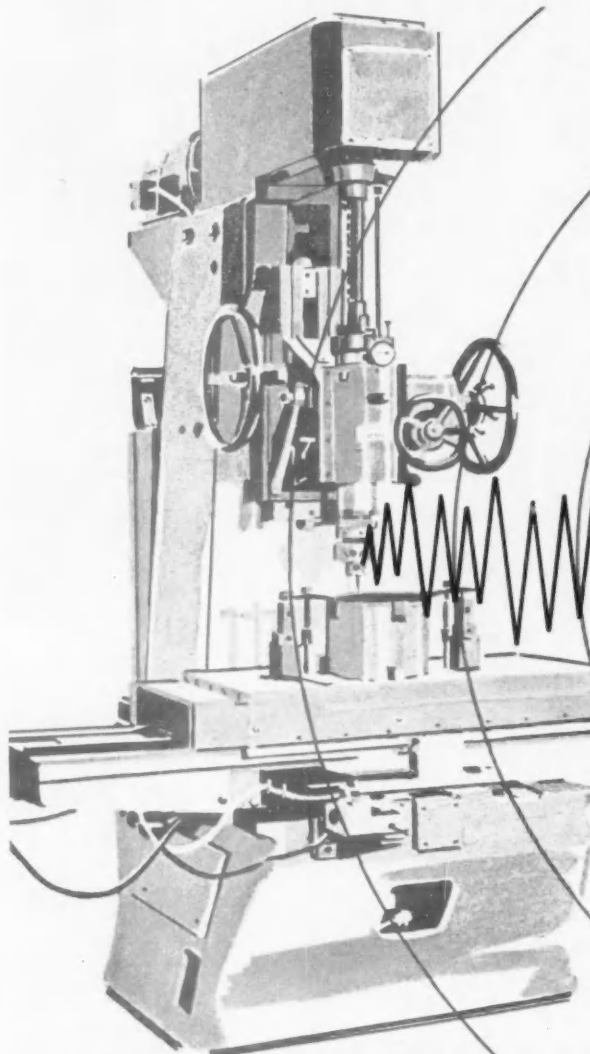
The AE Class E relay is a miniaturized version of the premium-quality Class B, with many of its best features. Perfect contact reliability exceeding 200 million operations is common.

AE is also equipped to supply wired and assembled, custom-built control units, or to help you develop complete systems.

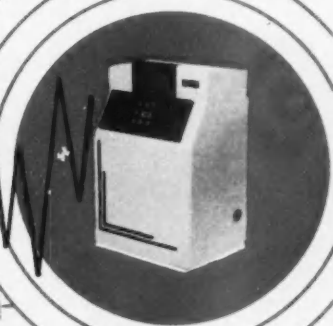
Want details? Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1702-E on *Relays for Industry*, and the new 32-page booklet on *Basic Circuits*.



AUTOMATIC ELECTRIC 
Subsidiary of
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A DYNAMIC NERVE CENTER FOR THE MACHINE TOOL INDUSTRY

A SINGER Achievement . . . the most direct approach to point-to-point positioning yet conceived. The SINGER Numerical Control System offers simplicity, reliability and economy, reducing costs of maintenance, labor and downtime.

DISCRETE POSITIONING: UP TO 40" OF TRAVEL. ACCURACY OF .001
SINGER Numerical Control makes possible a high degree of accuracy by a division of the measuring section and the motor drive within the system.

The SINGER System also features modular design, making

it possible to assemble basic units in a variety of control systems.

And, of prime importance, all modules and motors are designed, serviced and built by Diehl Manufacturing Company, a SINGER subsidiary.

To see, SINGER Numerical Control in action, visit the unique demonstration room at the Diehl Plant near Somerville, New Jersey. Here you can examine actual production records as evidence of the economy, reliability and accuracy of this advanced point-to-point positioning system. Call or write for an appointment at the address below.



DIEHL MANUFACTURING COMPANY

SUBSIDIARY OF THE SINGER MANUFACTURING COMPANY

Finderne Plant, Somerville, New Jersey

Telephone: Randolph 5-2200

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APRIL 1961

CIRCLE 87 ON READER SERVICE CARD 87



Now! Get premium features in a DVM priced at only \$940

Cubic Corporation announces the V-45—the first low-cost digital voltmeter with premium features. Now industrial users can buy a top-quality, precision four-digit instrument at a price they can justify—only \$940. Here are the premium features you get in a V-45:

Floating Input: Both sides of the input may be floated above or below ground. The floating input circuit provides more than 80 db rejection to 60-cps common-mode signals. A grounded input is also supplied.

Extended Range: A 10% extension is incorporated in each of the V-45's three ranges. Voltages up to 10.999 may be read on the 10-volt range; voltages up to 109.99 may be read on the 100-volt

range; and voltages up to 1099.9 may be read on the 1000-volt range. Therefore, the operator need not constantly shift back and forth between ranges when reading close to the normal upper limit of a range.

Transistorized Logic and Drive Circuit: The V-45 DVM uses construction techniques representing the latest state-of-the-art, with all-transistorized circuitry driving reliable stepping switches.

Cubic manufactures a complete line of quality digital instruments, including a-c and d-c voltmeters, ohmmeters, ratiometers, scanners and printer controls. Write for literature to Dept. CT-103, Industrial Division, Cubic Corporation, San Diego 11, California.

SPECIFICATIONS

MODEL V-45 DIGITAL VOLTMETER

Input Impedance: 10 megohms at balance.

Ranges: Manually selected, 10% extended range

Low ± 0.000 to ± 10.999 vdc

Mid ± 00.00 to ± 109.99 vdc

High ± 000.0 to ± 1099.9 vdc

Sensitivity: 1 millivolt

Sensitivity Control: Continuously variable from 1 digit to standby lockout.

Power Input: 105-125 vac, 50-60 cps,

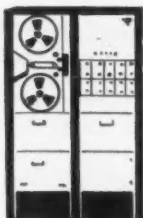
25 watts standby, 30 watts operating.

Dimensions: 19" wide, 5 1/4" high, 14" deep, rack or bench mounting with dust-proof switch and bridge section.

Average Balancing Time: Less than 2 sec.



cubic
CORPORATION



The earth trembles . . . a rumble is heard running along the ground . . . there's a deafening roar as the earth splits!

To catch this brief moment of seismic history on magnetic tape for electronic data processing may have required hundreds of hours of continuous recording . . . and mountains of tape. But now there's a new way to beat this tape consumption problem—Honeywell's New LAR 7500 Magnetic Tape System!

By recording at very low speeds of 0.3 and 0.6 ips, the LAR 7500 system can put 24 hours of data on a single reel of tape. With the use of ultra-thin 0.35 mil base tape, the system can record up to three days of data on a single reel. In addition, the LAR 7500 lets you playback over a large range of speeds without changing heads.

HONEYWELL INTERNATIONAL

Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

This new system also offers great potential as a practical and dependable recording device for atomic test detection systems based on seismograph techniques. Scatter propagation studies, tide and other wave motion studies are also well suited to LAR 7500's low-speed, high-capacity capabilities and foolproof tape handling system.

Get all the facts on the new LAR 7500 Magnetic Tape System by calling your nearby Honeywell field engineer. He'll give you valuable assistance in matching a Honeywell data system to your exact requirements. Be sure to ask about the Honeywell Automatic Wave Analyzer Systems for accurate and high-speed analysis of recorded data.

MINNEAPOLIS-HONEYWELL, Industrial Systems Division,
10721 Hanna Street, Beltsville, Maryland.

Honeywell



First in Control

SINCE 1886

**CAUGHT
IN
THE
ACT**

THE TAPE THAT CHANGED TV FOR ALL TIME

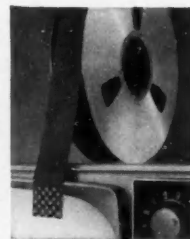
leads you right to rugged
SCOTCH® BRAND Heavy Duty Tape



THE TIE that binds television's top performer to instrumentation tape is strong—and it goes beyond the fact that the same expert team produces the best of both. "SCOTCH" BRAND Heavy Duty Tapes share a common heritage—and uncommon endurance—with "SCOTCH" BRAND Video Tape, the tape that puts a network TV show on the same "clock time" from Maine to California.

Similarities worth noting between the two: a similar high-temperature binder system, famous "SCOTCH" BRAND high potency oxides, a similar ability to resist tremendous speeds, pressures and temperatures while providing high resolution.

Let's look at the record of "SCOTCH" BRAND Video Tape and see what message it has for the user of instrumentation tape. On a standard reel of video tape like that shown here, some 1½ million pulses per second must be packed to the square inch—on a total surface area equal to the size of a tennis court. The tape must provide this kind of resolution while defeating the deteriorating effects of high speeds, pressure as high as 10,000 psi and temperatures up to 250°F.



The fact is that video tape must be essentially perfect. And it's a matter of record that thus far only the 3M experts have mastered the art of making commercial quantities of video tape that consistently meet the demands of the application.

Significantly, the high-temperature binder system developed for "SCOTCH" Video Tape is first cousin, only slightly removed, to that used in the Heavy Duty Tapes. It's this special feature that has given Heavy Duty Tapes their exceptional wear life.

The moral emerges: for tape that provides the best resolution of high and low frequencies under the severest conditions, turn to "SCOTCH" BRAND Heavy Duty Tapes 198 and 199.

They offer the high temperature binder system, plus the same high quality and uniformity that distinguish all "SCOTCH" BRAND Tapes. As the most experienced tape-makers in the field, 3M research and manufacturing experts offer tape of highest uniformity—from reel to reel and within the reel. Check into the other "SCOTCH" BRAND constructions: High Resolution Tapes 158, 159 and 201; High Output Tape 128; Sandwich Tapes 188 and 189; and Standard Tapes 108 and 109.

Your 3M Representative is close at hand in all major cities. For more information, consult him or write Magnetic Products Division, 3M Co., St. Paul 6, Minnesota.

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SCOTCH BRAND MAGNETIC TAPE
FOR INSTRUMENTATION

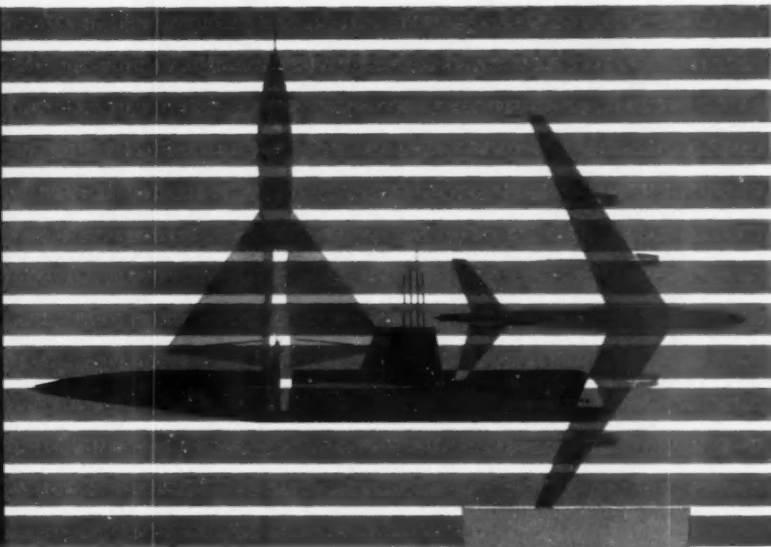
MINNESOTA MINING AND MANUFACTURING COMPANY
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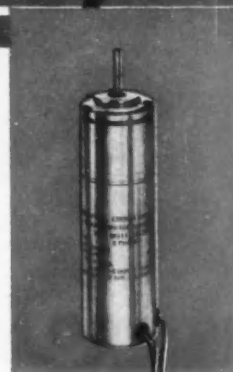


Consistent reliability, unit after unit, is assured when you use Edison motor-generators. Because reliability is designed into these components, and painstaking inspection follows every step of their construction, you can be sure each and every Edison motor-generator will meet your most exacting requirements.

Designed to meet and exceed the requirements of MIL-S-17806, MIL-S-17807 and MIL-E-5272B, these components give you *performance reliability* you can count on.

Special one-piece motor-generator housings provide the compact, rugged construction needed for consistent performance under extreme operating conditions. Unlike off-the-shelf components, Edison servo-motor-generators, available in production quantities, are specifically designed to operate as integral parts of your electro-mechanical system.

For complete information on Edison motor-generators and motor-generator gear head assemblies, write for Catalog 3044.

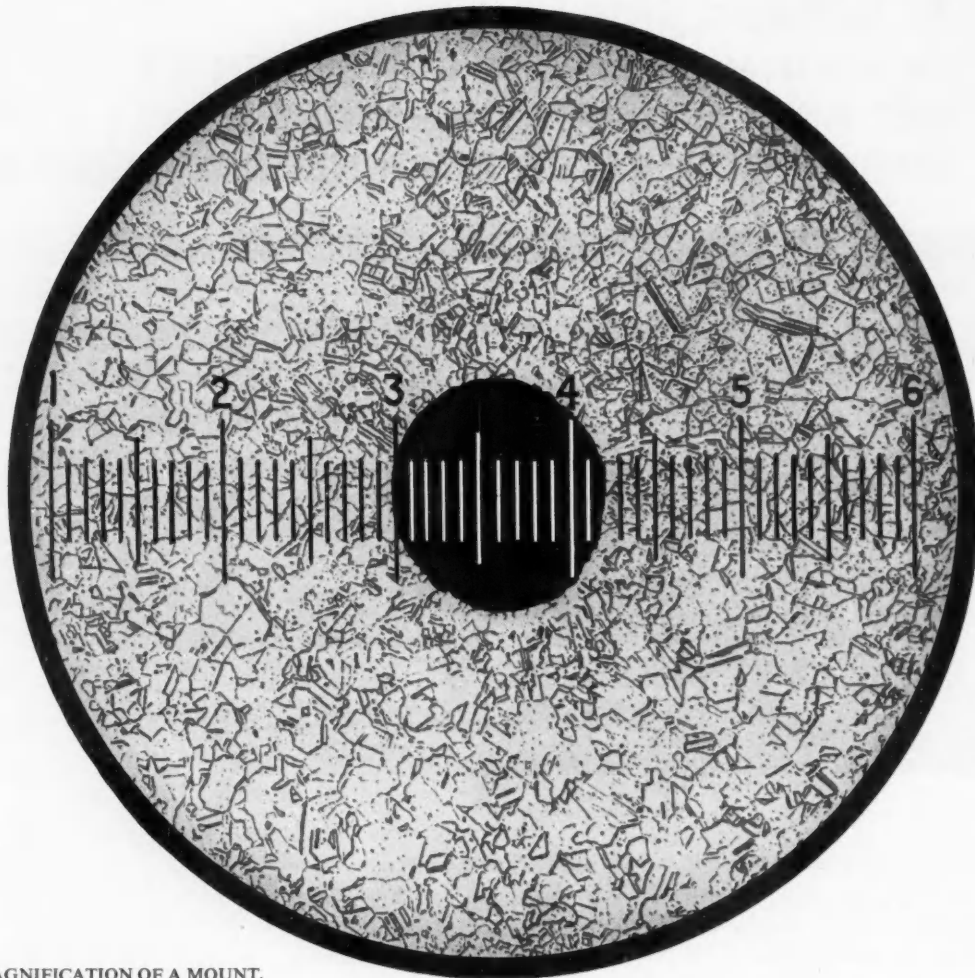


*These motor-generators
are available with
or without gear heads*

Thomas A. Edison Industries
INSTRUMENT DIVISION

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100X MAGNIFICATION OF A MOUNT.
Each division .001 in.

Capillary ID size is checked under 100x magnification

—yet this critical inspection is only 1 of 3 used to check ID of Superior capillary tubing

At Superior, in checking the ID size of capillary tubing we don't rely on only one reading from our inspection microscope, we require four. Then we double-check in two other ways—one the use of a relatively simple plug gage, the other a comprehensive flow inspection to ascertain the average ID dimension. These inspections also give you assurance of a

free passage through the bore, uniformity of ID surface and a satisfactory grain structure.

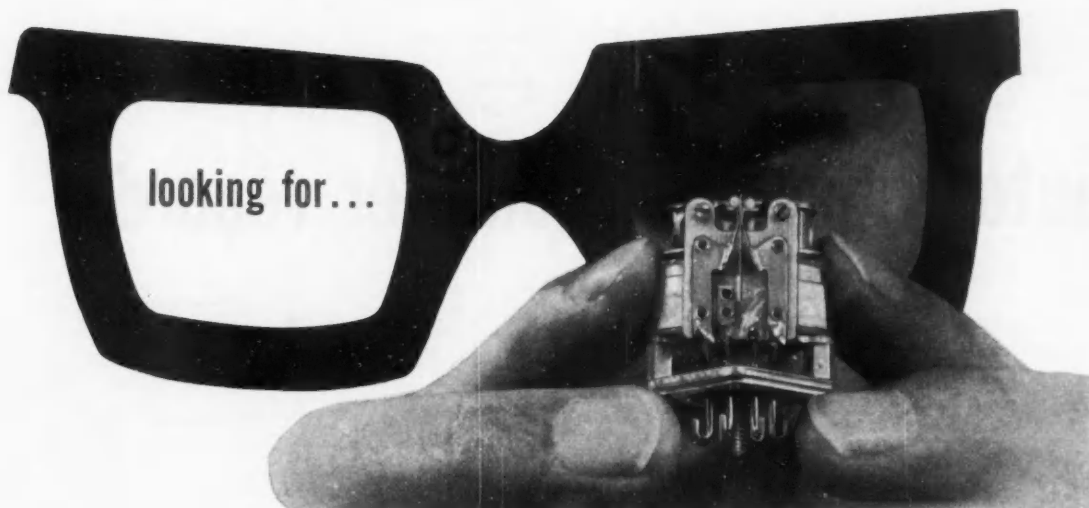
Superior has spent years in the development of manufacturing processes and quality control procedures for the production of close tolerance capillary tubing. ODs range up to $\frac{3}{16}$ in., IDs from .004 through .040 in. Analyses include Types 304, 316, 321, 347 and 446 stainless; also Monel, Inconel, nickel and carbon steel alloys. Data Memorandum No. 11 gives complete details—let us send you a copy. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

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The big name in small tubing
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All analyses .010 in. to $\frac{5}{8}$ in. OD—certain analyses in light walls up to 2½ in. OD

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RELIABLE RELAYABILITY?

specify the VG and VGS series

Elgin's hermetically sealed VG and VGS miniature rotary relays provide high sensitivity and high contact rating in less than one cubic inch. The VGS Series operates on the power of a single transistor.

another example of



relayability

VG AND VGS SPECIFICATIONS

contact arrangement	DPDT (2 form C)
contact rating	5 amps @ 26.5 VDC or 115 VAC 60 CPS resistive load
min. oper. power @ 25°C	VG: 340 milliwatts VGS: 125 milliwatts
max. oper. time @ nom. oper. power	VG: 6 milliseconds VGS: 20 milliseconds
max. release time	10 milliseconds
duty	continuous
shock	VG: 100G VGS: 50G (MIL-R-5757C, shock test II)
vibration	10-55 CPS total max. excursion of 0.060 in.; 15G, 55-2000 CPS
amb. temp. range	-65°C to +125°C
life	100,000 operations @ rated resistive load (MIL-R-5757C)
enclosure	evacuated @ 2.5 in. HG ABS, degassed @ 10 microns and 170°C, dry nitrogen filled & hermetically sealed
dimensions	H—0.875"; W—0.875"; L—1.125"
weight	1.5 ounces

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latest data

ELGIN advance RELAYS

THE ELECTRONICS DIVISION OF ELGIN NATIONAL WATCH COMPANY
2435 NORTH NAOMI STREET, BURBANK, CALIFORNIA



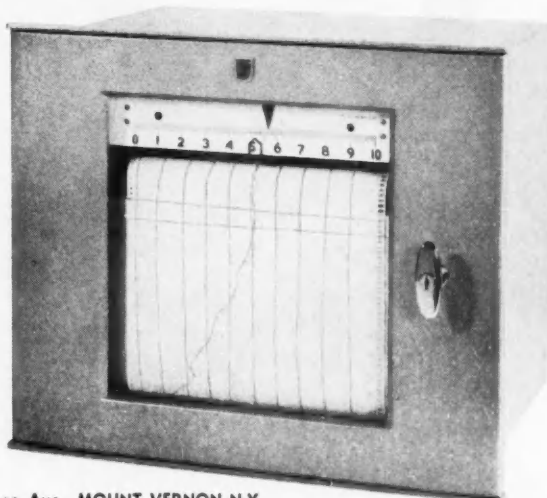
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type PR 2210

- laboratory accuracy in an industrial instrument
 - switchable measuring ranges in a single unit
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 - ample room provided for incorporation of supplementary gear
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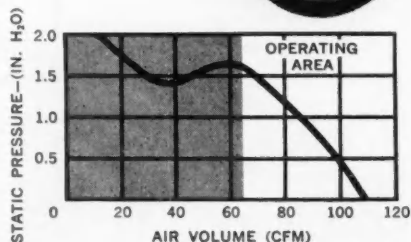
U.S.A.: Philips Electronics Inc., Instrument Division, 750, South Fulton Ave., MOUNT VERNON N.Y.

Canada: Philips Electronics Ltd., 116 Vanderhoof Ave., TORONTO - Ontario

Overseas inquiries: N.V. Philips' Gloeilampenfabrieken - Eindhoven - Holland

CIRCLE 238 ON READER SERVICE CARD

3" dia. x 3¼" long, 16 ounces



NEW VANEAXIAL AC/DC UNIVERSAL BLOWER

Globe's VAX-3-GN Universal Blower gives you 110 cfm. free air, with a design point of 68 cfm. at 1.5" H₂O—on either 115 v.d.c. or 115 v.a.c., 60 cycle power. Other voltages can be supplied. Nominal speed is 14,000 rpm.

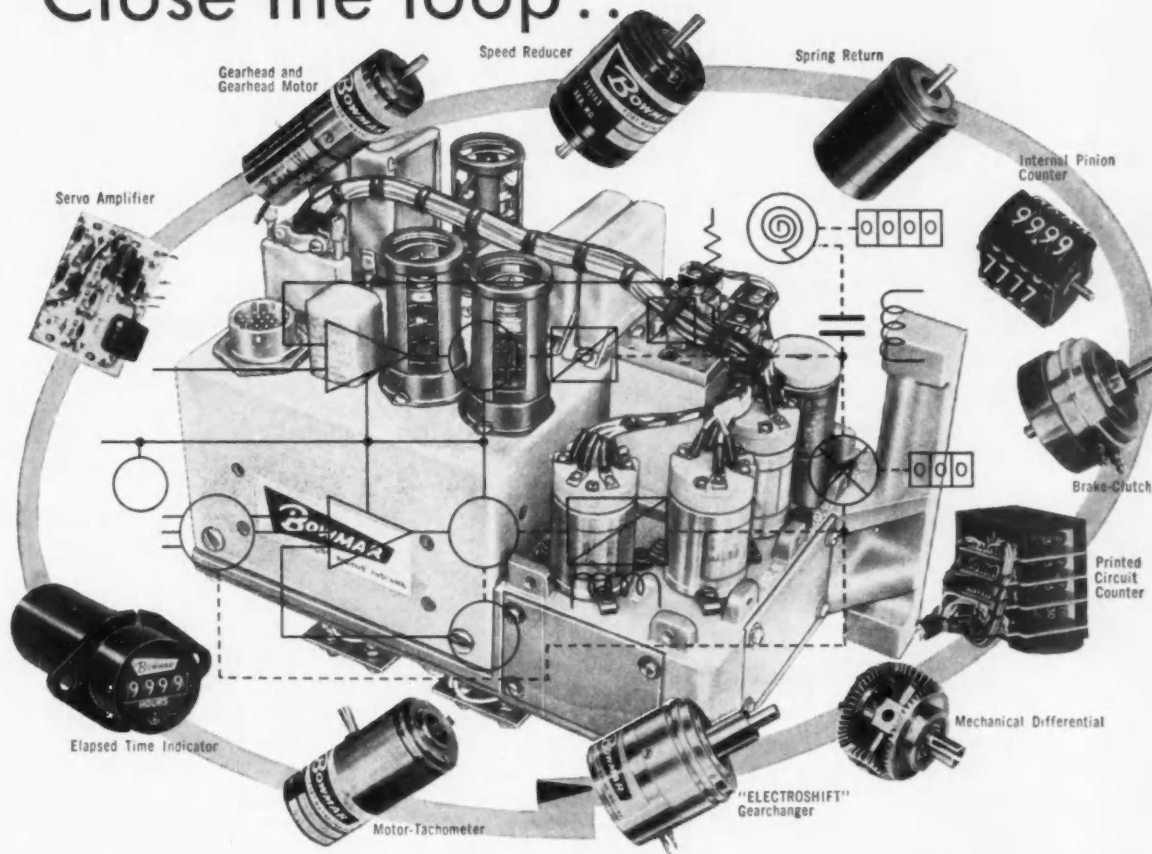
You can standardize on this extremely versatile blower for ground support and commercial electronic cooling. It's designed to meet MIL specs, having passed shock and vibration per MIL-E-5272. Production tooling makes this blower economical. Prototypes can be in your hands tomorrow (telephone BA-2-3741 for part no. 19A908); production orders normally delivered in a short time.

Rugged mechanical protection is provided by the black anodized aluminum housing and propeller. Mount by clamping to servo ring at either end. Nominal life exceeds 1000 hours. Max. current is 0.47 amps at free air delivery. Request Bulletin GNB from Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio.

GLOBE

GLOBE
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Close the loop...



buy the part or the package!

- PRECISION MECHANICAL DEVICES
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You get "ONE STOP" capability in all phases of precision control and indication from Bowmar. This capability is available for design and production of all types of standard or specialized precision COMPONENTS. With equal facility Bowmar can engineer and integrate these devices into complete SERVO PACKAGES.

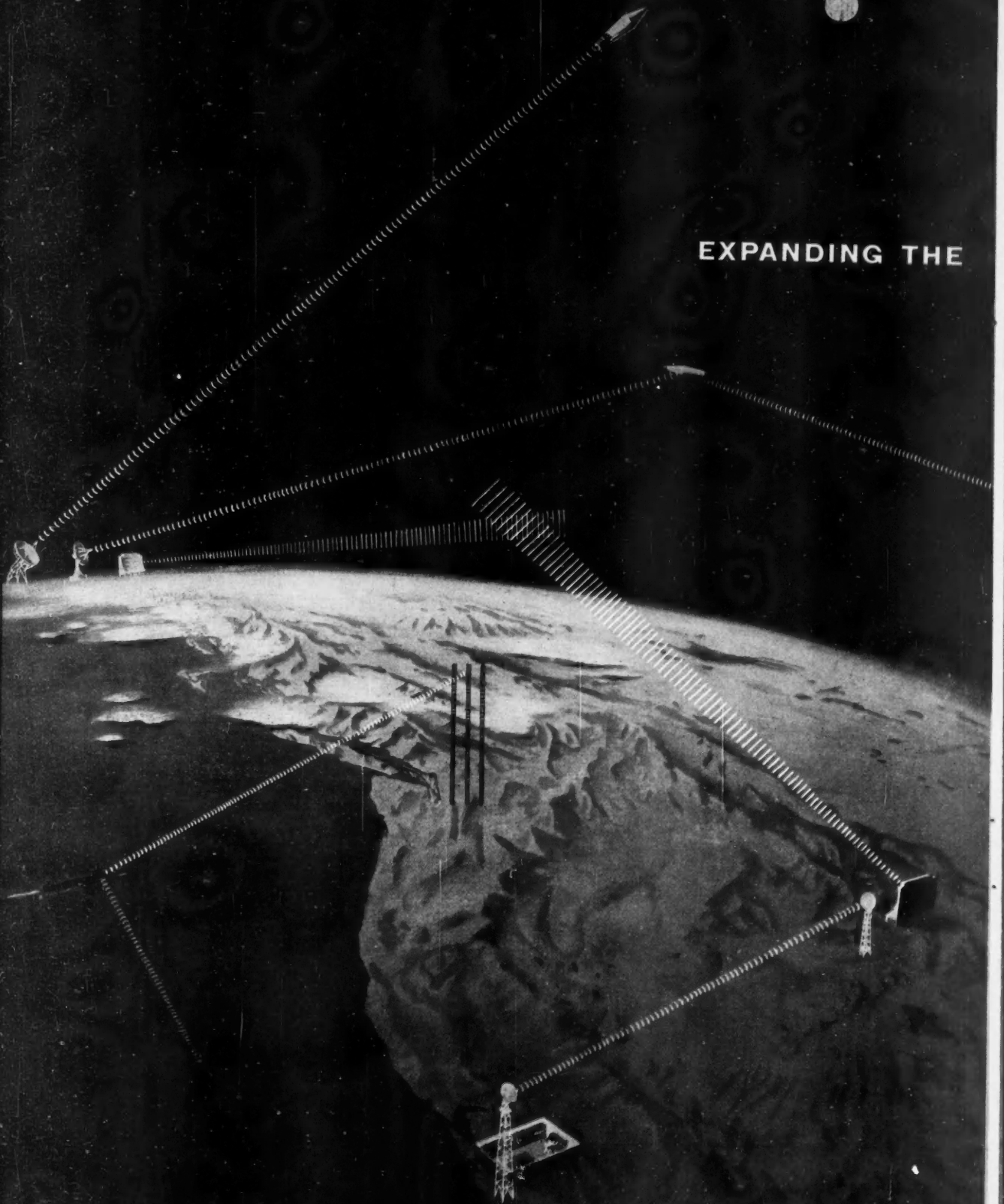
Inventive miniaturization, further weight reduction and increased reliability can be part of the benefits to your precision control or indicating systems.



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8000 Bluffton Road
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Telephone Sherwood 3121—TWX FW 296

EXPANDING THE





Herodotus, the historian, records (490 B.C.) the use of burnished shields for military signaling. This was the forerunner of the heliograph, invented by Sir Henry C. Mance, which came into wide use centuries later.

FRONTIERS OF SPACE TECHNOLOGY IN COMMUNICATIONS

Lockheed's interest in developing the science of communications extends from the depths of the oceans to deep space. Its Missiles and Space Division research programs deal with the development and application of statistical communication and decision theory in such areas as countermeasures; telemetry multiplexing and modulation; scatter communications; multiple vehicle tracking; millimeter wave generation and utilization; sonic signal detection and processing; avoidance of multipath degradation; and interference avoidance.

Associated research and development efforts are directed toward propagation studies and advanced antenna design; low noise amplifiers; vehicle borne signal transmission and reception, data storage and processing; solid state materials and devices.

The scope of such activities extends from advanced studies of naval communication problems on and under the oceans; the many applications to satellite vehicles; on to the specialized communication problems of deep space explorations. Latter needs are exemplified by high frequencies, low weight and power, high stability, low effective bandwidth, extreme reliability and basic simplicity requirements.

Engineers and Scientists: Investigating the entire spectrum of communications is typical of Lockheed Missiles and Space Division's broad diversification. The Division possesses complete capability in more than 40 areas of science and technology — from concept to operation. Its programs provide a fascinating challenge to creative engineers and scientists. They include: celestial mechanics; communications; computer research and development; electromagnetic wave propagation and radiation; electronics; the flight sciences; human engineering; magnetohydrodynamics; man in space; materials and processes; applied mathematics; oceanography; operations research and analysis; ionic, nuclear and plasma propulsion and exotic fuels; sonics; space medicine; space navigation; and space physics.

If you are experienced in work related to any of the above areas, you are invited to inquire into the interesting programs being conducted and planned at Lockheed. Write: Research and Development Staff, Dept. M-18B, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense industrial security clearance required.

Lockheed / **MISSILES AND SPACE DIVISION**

*Systems Manager for the Navy POLARIS FBM and the Air Force AGENA
Satellite in the DISCOVERER and MIDAS Programs*

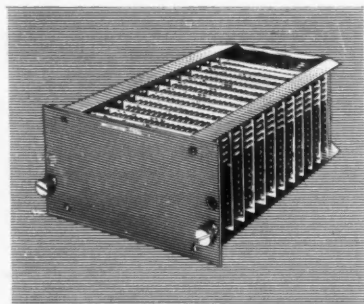
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EXPERIENCE IN DEPTH...COMPUTING, PLOTTING, INSTRUMENTS, SYSTEMS, PROCESS CONTROL

ULTRA FAST AND ACCURATE ELECTRONIC MULTIPLIERS

Part of a new generation of electronic multipliers, designed and developed by EAI, the new Multiplier Model 7.036 combines unusually wide bandwidth with high static accuracy.

Virtually maintenance-free, the Multiplier 7.036 utilizes a unique quarter-square technique that achieves high static multiplying accuracy without the usual resulting deterioration of frequency response. Diode function generators develop the square quantities from x and y inputs, eliminating the need for internal amplifiers.



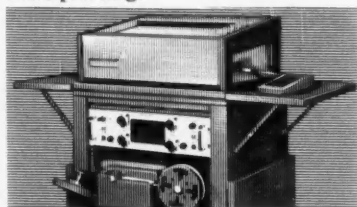
Here are the outstanding features of this new multiplier:

- Outstandingly low output noise—20 millivolts maximum
- Solid state design insures reliable operation
- Holds calibration for extended periods
- Frequency response—over 20 kc
- Static accuracy 0.04%—Zero error 0.01%
- Drift-free, internally temperature-compensated
- Can be added to expand existing systems without modification

For specific details on the EAI Multiplier 7.036, write to Dept. 14.

DIGITAL PLOTTING - WITH ACCURACY AND LOW COST

Dramatic improvement in the accuracy of 11 x 17 inch x-y plots of digital data is now available with EAI Series 3100 DATAPLOTTER. The low cost of this instrument makes available a rapid and economical substitute for laborious hand plotting.



Outstanding features of EAI Series 3100 DATAPLOTTERS include:

- System accuracy up to 0.175% of full scale
- Punched card, tape or keyboard input
- Plotting speeds up to 80 points per minute
- Provisions for "off-board" origin
- Compact, single-cabinet design. Punched card reader external
- Adaptable to any computer system
- Accepts analog and digital inputs

Transistorized control circuitry insures high-speed, accurate, reliable operation. The EAI Series 3100 DATAPLOTTER makes readily available a low-cost tool for fully exploring experimental design problems. It is particularly applicable in data reduction and instrumentation installations. As a management tool, it is valuable for the conversion of computer intelligence to graphic representation of sales, production and cost data.

For specific details on the Series 3100 DATAPLOTTERS or complete data on the full line of EAI DATAPLOTTERS, write to Dept. 15.

THE STANDARD FOR RANGE INSTRUMENTATION

AMR EETF
PMR EAFB
EGTR NOTS
WSMR WOOMERA

These are some of the ranges equipped with EAI Range Instrumentation equipment. Since 1946, more than 300 EAI computers, plotters and recorders have been installed on test ranges throughout the world.

Electronic Associates Range Instrumentation equipment includes:

- X-Y Plotters
- Polar-to-Cartesian Coordinate Computers
- Cartesian-to-Polar Coordinate Computers
- Analog-to-Digital Converters
- Digital-to-Analog Converters
- Digital Voltmeters
- AC-DC Converters
- Special Purpose Computer Assemblies

Systems studies at EAI encompass the most advanced computer techniques involving simulation and ultra fast and precise logic circuits for data processing.

EAI Range Instrumentation is used in the following areas:

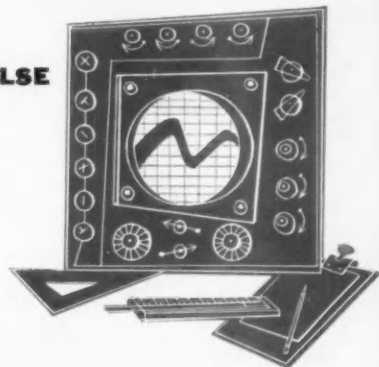
- For display of tracking data
- For target acquisition by slaved radar
- For interconnection of digital and analog devices
- For automatic system checkout
- For numerical displays
- For special computer applications

EAI capabilities in Range Instrumentation planning are the result of over 45 man-years of engineering experience. This experience is available to you by writing to Dept. 16.

EAI

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Career Opportunity for Engineers—
Graduate or advanced degrees
in EE, Physics, Math—
call or write Gordon Strout,
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Will the Government Slow Modernization?

Equipment mechanization with automatic control is moving too fast. That is the consensus of labor spokesmen in President Kennedy's new administration. And the U.S. Government will soon take some steps that could slow the rate of mechanization.

After a whirlwind two-day tour of the Midwest in February, Labor Secretary Arthur Goldberg returned to Washington bemoaning the level of unemployment. At a press conference, he placed a lot of the blame on work forces reduced in size by automatic equipment, vowed to establish a new section in the Department of Labor to wrestle with the problems introduced by automatic equipment.

Goldberg's action culminates a steady growth of union opposition to mechanization (CtE, Sept. '60, p. 125-129). Last fall, labor leaders like the United Auto Workers' Walter Reuther and United Steel Workers' David MacDonald advocated schemes for slowing the introduction of automatic equipment. Now the resistance is more than talk.

On the West Coast last month, after the Pacific Maritime Association (an organization of dock and ship operators) and the International Longshoremen's and Warehousemen's Association had concluded what many call a model automation pact—the union will allow the employers' group to introduce any labor saving device while the employers have agreed to pay a guaranteed wage to dock workers—officials of the Western Conference of Teamsters warned they would not recognize the pact, would strike the docks if labor saving devices cut out any teamster jobs.

At February's AFL-CIO summit meetings in Florida, how the federal government could control the pace of automation was the top topic of private conversations. One official told a CtE reporter, "Organized labor is desperately afraid of too fast development of automation".

Goldberg is attempting to convince labor leaders that the U. S. Government will do something to protect workers affected by automation. The Labor Secretary himself feels that automation is the toughest labor-management issue facing the country. It has, says Goldberg, priority for organization before the president's newly conceived Labor-Management Advisory Committee.

Even Goldberg doesn't know what his new automation section will do. He is still trying to work out organizational details with

**Blame
automation**

Buck pacts

ACCURACY PERMANENTLY ASSURED BY TAUT BAND SUSPENSION

New Westinghouse Switchboard Instruments

give you the proved benefits of Taut Band Suspension in your choice of 4½" full view 250° scale or 6" rectangular 100° scale designs.

Westinghouse a-c and d-c Taut Band Suspension instruments offer you definite advantages over pivot-jewel bearing types. They have no friction; provide higher sensitivity; offer almost infallible repeatability; are more durable, requiring less instrument repair and replacement. Accuracy is not affected by severe vibration or shock — an important factor in eliminating instrument damage during shipment of individual units or complete switchboards.

This outstanding performance is the direct result of Westinghouse *tbz** — the remarkable suspension system that has proved its superiority over the past two years in all types of applications. For complete details on these new instruments and a sample of Taut Band Suspension, write Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. You can be sure . . . if it's Westinghouse.

*Trademark of Westinghouse Taut Band Suspension instruments

J-40537

All Westinghouse instruments meet or exceed the requirements of ASA standard C-39.1.



Westinghouse



the Bureau of the Budget. But Goldberg's past record hints at what industry can expect.

At hearings to confirm his nomination, he told the Senate Labor Committee "We should push the process of accelerating automation, but we should adopt programs to protect human beings in the process. We should get the full potential of automation and at the same time safeguard against hardships that happen to individuals, to families, when automation takes place".

Goldberg, as legal counsel and negotiator for the United Steel Workers, was involved in a number of bitter steel strikes that amounted to automation disputes, like the 160-day steel strike in 1959, over work rules. He has conceded that workers may resort to featherbedding or hanging on to obsolete work rules as a way of protecting their jobs.

In 1956, Goldberg's steel workers negotiated their supplementary unemployment benefits clause that set up a company-paid fund for laid-off steel workers. He sees the SUB plan as the first of the automation pacts in industry.

Some Washington viewers are saying that the Labor Secretary ultimately will model the automation section after the Bureau of Labor Statistics. Its assignment: to gather from all of industry what developments are going on, what labor skills are being affected, and what methods of retraining workers are being carried out.

If this were the end, industry would not have much to be alarmed about. But Goldberg has ambitions to expand the status and scope of the Department of Labor. He wants the department to exert more influence on national economic planning. He envisions his department going beyond the data collection function, recommending programs such as when and where to move workers displaced by automation; retiring workers at 60 instead of 65 or later; starting severance pay settlements for workers laid off during their working years.

All this means that control engineers are likely to have to modify their economic justification studies applied to the installation of new automatic equipment. Both makers and users of control and instrumentation have much at stake in the government's new view toward modernization.

Goldberg's record

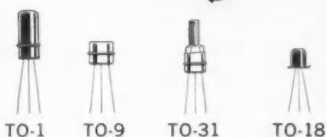
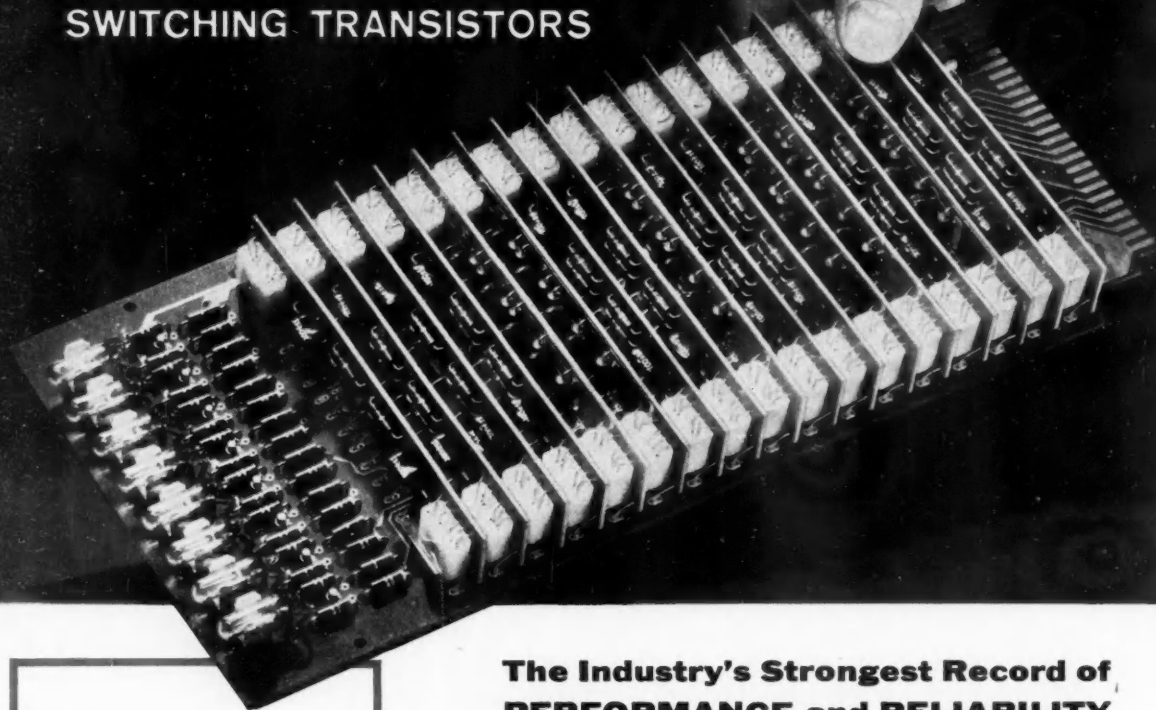
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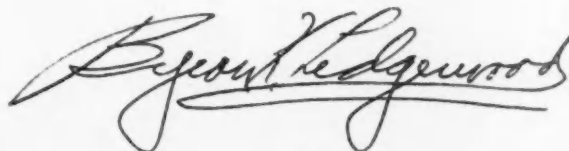
Capacity vs Unit Cost

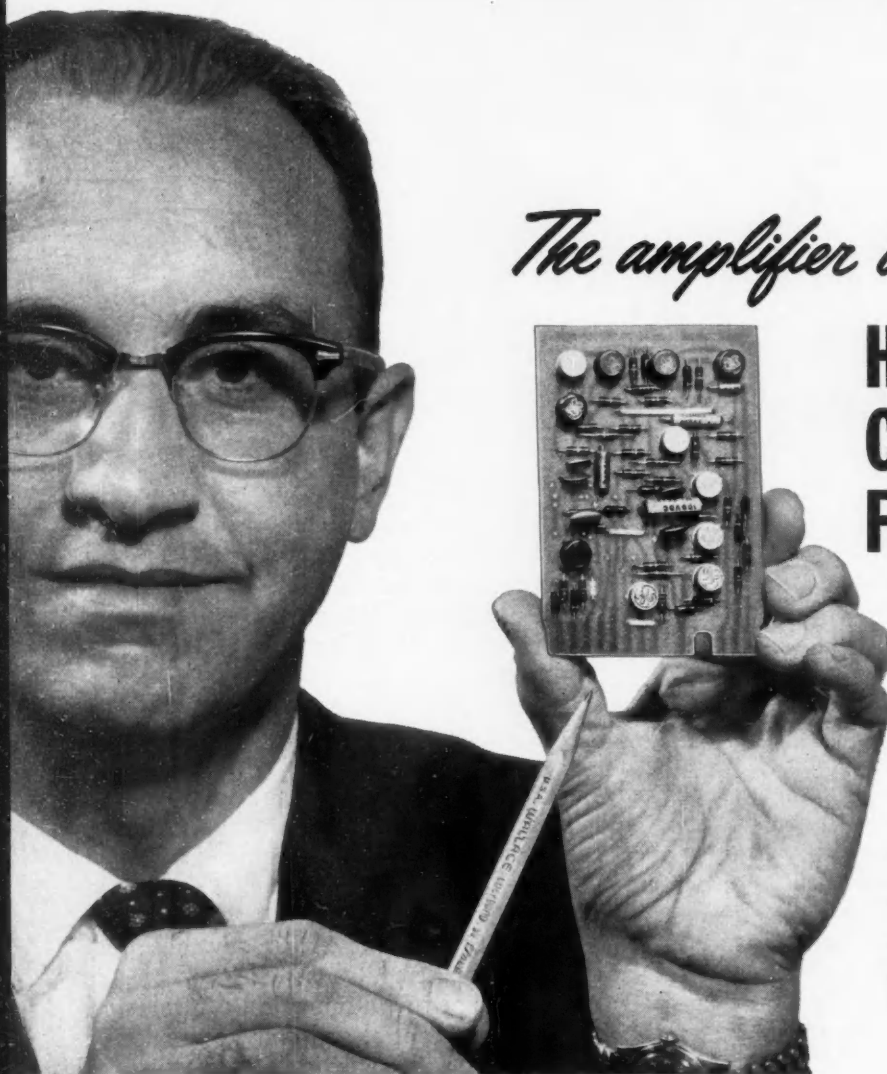
Look around you—at the newspapers, the magazines, the plants and factories in your home town. All sources reveal that portions of U. S. industry are running well below their maximum capacity, and even those that are not are facing the competitive turmoil of a buyers' market. These problems of surplus capacity and competition raise an interesting question: Just how will industry invest its capital funds in the near future?

Certainly most industries will not be increasing capacity just for capacity's sake. Rather they will seek ways to produce the same or a better product at lower unit costs, through new production and processing techniques or through the modernization of existing capacity. Each industry will invest in equipment that will increase throughput, reduce reject rate, decrease direct labor, minimize inventory requirements, optimize business operations. This leads to business for suppliers of conventional capital goods and, more important to you, it means the control field must expand since the benefits to be gained are exactly those that accrue through the proper use of automatic control systems.

Machine tools are likely to be equipped with numerical control, steel mills and furnaces with automatic gage control and data accumulators, and chemical and petroleum processes with analytical instruments and on-line control computers. The common denominator is the automatic system. The control industry will boom not with one user group or with suppliers of one particular type of capital goods but with all industries as they pursue quality at low cost.

As control engineers your importance will increase, but only if you watch dollars as closely as frequency response. Find new applications for automatic systems. Search for all potential gains and put dollar signs on them. Your story backed up by facts and figures should make welcome listening for management in today's economy. Remember, your job in the future will be not only to increase productive capacity, but more important, to decrease unit costs.





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Using Pneumatic Analog Computing Elements for CONTROL

Many opportunities exist in process operations for incorporating computing operations in the control scheme. When the particular application is relatively small and well defined, reliable pneumatic analog devices offer a low-cost, profitable way of achieving computing control.

The needed computation is obtained by proper interconnection of simple pneumatic analog computing elements that can perform arithmetic, linearizing, differentiating, integrating, and logic functions. These elements and their operation are detailed here. The article concludes with a typical control system employing such devices for computing and optimizing.

CHARLES L. MAMZIC, Moore Products Co.

A. ADDING, SUBTRACTING, AND INVERTING

Two basic computing relays, the pneumatic force balance type and the mechanical force balance type perform simple addition, subtraction, and inversion of pneumatic signals.

In the pneumatic force balance relay, Figure 1, signal pressures in chambers A and B act downward and the signal pressures in chambers C and D act upward on their diaphragms. Here, all four diaphragms have the same effective area. Spring force K is adjustable over a full range of positive and negative forces. Any unbalance in the net working forces moves the diaphragm assembly and its integrally connected nozzle seat, the change in nozzle seat clearance with respect to the detecting nozzle thereby adjusting the output pressure T in chamber D until force balance is restored.

The basic equation describing relay operation is

$$T = A + B - C - K$$

When performing a specific computation, all unused input ports must remain vented to atmospheric pressure.

In the mechanical force balance computing relay, Figure 2, each bellows has the same effective area. Relay output pressure acts on bellows T. Pressures

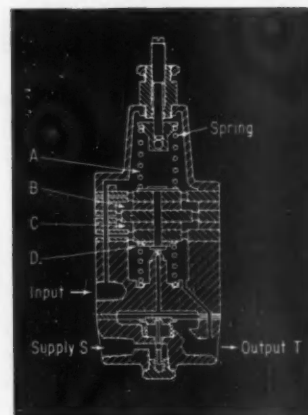
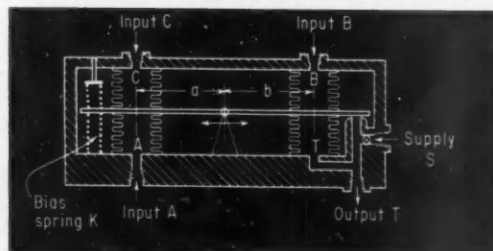


FIG. 1.
PNEUMATIC
ADDING RELAY.

FIG. 2. PNEUMOMECHANICAL ADDING RELAY.



in chambers A and B increase output, while pressure in chamber C decreases output. The output pressure automatically changes to maintain all forces in balance. Spring force K is fully adjustable.

The basic equation for this relay is

$$T = \frac{a}{b} (A - C) + B \pm K$$

If the lever ratio a/b is unity, the equation becomes

$$T = A + B - C \pm K$$

Adding of two variables can be performed by either relay when their pressures are connected to

chambers A and B. Subtraction obtains by connecting the minuend to either chamber A or B and the subtrahend to chamber C.

A signal can be inverted, or reversed, with either relay by loading the signal into chamber C and adjusting spring K for the proper positive suppression. The equation for inverting signal C is

$$T = K - C$$

For example, for inverting a 3 — 15 psi signal to a 15 — 3 psi signal, the spring is set to give an 18-psi positive suppression ($K = +18$). This makes the output 15 psi for a 3 psi input.

B. ADDING MULTIPLE INPUTS

From three to six variables can be added in a computing relay, Figure 3, that is similar to the relay in Figure 1 except that more diaphragms provide additional input chambers and output feedback chambers. Here, the particular relay sums five inputs and produces an output proportional to the average of five inputs:

$$T = \frac{A + B + C + D + E}{5} \pm K$$

The averaging feature is especially desirable in analog computing, since all signals—both input and output—are maintained in the same standard range without requiring special scaling of signals.

C. MULTIPLYING AND DIVIDING

A common multiplier-divider is the Sorteberg force bridge, Figure 4. Input pressures act on bellows in chambers A, B, and D. The output signal is the feedback pressure in chamber C. The bridge contains two weigh beams, WL and WR, pivoting on a common movable fulcrum. Each beam operates in its associated feedback (balancing) loop. Any unbalance in moments on the left beam moves the fulcrum position until the left beam's moment-balance is restored. Any unbalance in moments on the right beam results in a change in output pressure until the right beam's moment-balance is restored. Therefore, the equations characterizing the balanced force bridge are

$$A \times a = B \times b$$

$$D \times a = C \times b$$

and
Thus
or

$$A \times C = B \times D$$

$$C = (B \times D)/A$$

Multiplication results when the two input variables are connected to chambers B and D. Division obtains when the dividend is connected to either chamber B or chamber D, with the divisor connected to chamber A. Simultaneous multiplication and division results, as the immediately preceding equation shows, when chambers B, D, and A are connected to signal pressures.

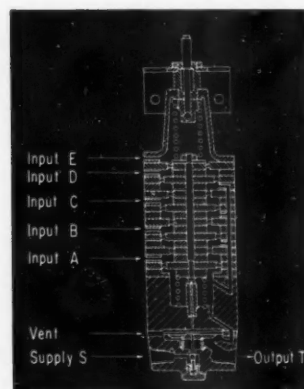


FIG. 3.
MULTIPLE INPUT
ADDING RELAY.

Two other types of multiplier-dividers are available. One, similar to the relay in Figure 2, has a pneumatically adjusted fulcrum. In the other, one variable changes a vector angle through an open-loop adjustment, with a second variable serving as the input to the vector-balance transmitter. One advantage of these two multiplier-dividers is that suppressed range signals representing such variables as pressure and temperature can be used directly, whereas the Sorteberg force bridge requires inputs proportional to the absolute values of these variables.

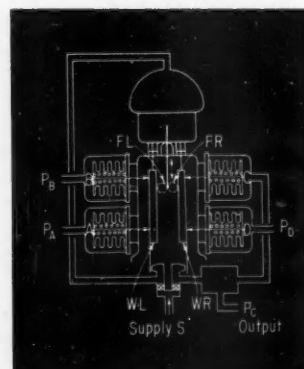


FIG. 4.
SORTEBERG
FORCE BRIDGE.

D. MULTIPLYING BY A CONSTANT

Scaling, a common term signifying multiplication by a constant, can be accomplished by pressure transmitters, proportional controllers, and adjustable ratio relays. When the application fixes the scaling factors—for example, when flow signals are scaled to the same range prior to addition or subtraction—the pressure transmitter appears to be the best choice from the standpoint of accuracy, reliability, and cost. When scaling factors are to be modified frequently, as when the factors represent revenue or cost, a good choice is the adjustable ratio relay.

An all-pneumatic ratio relay, Figure 5, contains a pressure divider circuit consisting of a fixed restriction R_f and a variable restriction R_v in series. The input signal produces a flow through the two restrictions and into a 3 psi reference pressure maintained by a datum regulator. The pressure at the junction of the two restrictions, the scaled signal pressure, is a function of relative resistance:

$$K = \frac{R_v}{R_v + R_f}$$

The scaling factor K is determined by the setting of the variable restriction. The scaling adjustment is available on the front panel. A duplex pressure

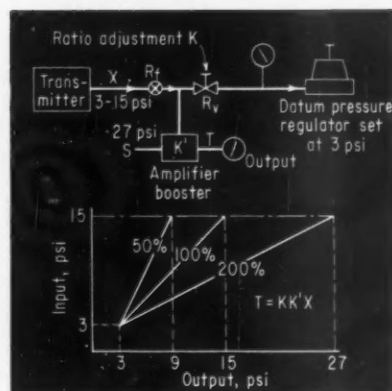


FIG. 5. SCALING OR RATIO RELAY.

gage indicates input and output pressures.

The pressure divider attenuates only; its gain K is less than unity. However, an amplifying relay adds a fixed gain K' greater than unity, the over-all scaling factor KK' then being adjustable through values greater than unity. Therefore,

$$T = KK'X$$

The term KK' determines the input-output slope.

E. DIFFERENTIATING

The pneumatic differentiation relay, Figure 6, produces an output directly proportional to the rate-of-change of input. Similar to the relay in Figure 1, this one has an effective annular diaphragm area in chambers B and C more than ten times the effective area of the smaller diaphragms in chambers A and B, thus giving a gain greater than ten. The input signal flows unrestricted to chamber B and passes through an adjustable restriction to chamber C. When input pressure changes, a differential pressure develops across the restriction and the output varies according to the difference. Thus, during a change in input signal the output develops a signal related to the rate-of-change of input. When the input pressure is steady, the forces in chambers B and C cancel, with the result that the net output pressure is equivalent to the spring setting.

For accurate results, this differential must be directly proportional to the input rate of change. A needle valve restriction produces laminar air flow which provides a linearly proportional volumetric flow. But the differential pressure across the restriction is a function of the mass flow which varies with static pressure because of air compressibility. Without compensation, the compressibility error is about 25 percent. Such an error can be fully compensated, however, by adding a variable volume to chamber C. As the static pressure increases,

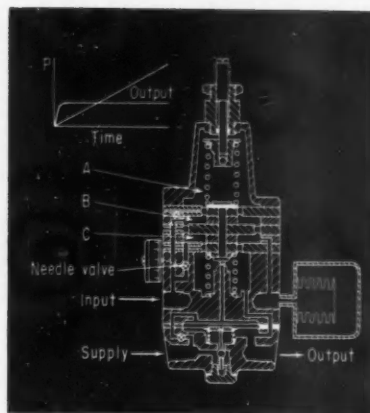


FIG. 6. DIFFERENTIATION RELAY.

tending to make the differential smaller because of higher mass flow rate, the volume increases proportionally to maintain a constant differential. The constant differential means that the output signal will be directly proportional to the input rate of change. Such linearity is especially desirable when the differentiated signal is employed in a computing scheme. The needle valve setting determines the rate time constant.

F. INTEGRATING

Integration, the inverse of differentiation, produces an output directly proportional to an error signal accumulating with time. Figure 7 shows an integration relay. The input signal determines the pressure differential across the needle valve restriction. As with the differentiation relay, laminar flow across the needle valve directly relates volumetric flow to the differential pressure. The mass flow (which determines the accumulated pressure) still varies with static pressure because of compressibility. This effect is compensated by connecting a variable volume to chamber A. The needle valve sets the integrator's time constant.

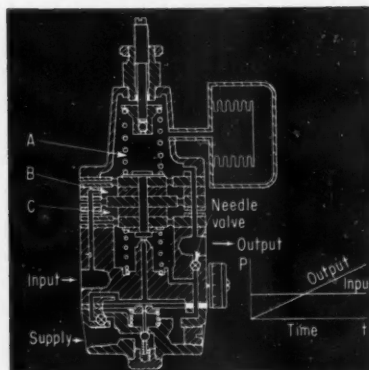


FIG. 7. INTEGRATION RELAY.

G. SQUARE ROOT EXTRACTING

Typically, square root extraction is regularly required to linearize flow measurements determined from differential pressure signals developed across an orifice inserted in a pipe through which the flow occurs. The resulting linearized signals are then proportional to the flow and suited for further computations such as addition and multiplication.

The Sorteberg force bridge, Figure 4, accomplishes square root extraction by connecting output

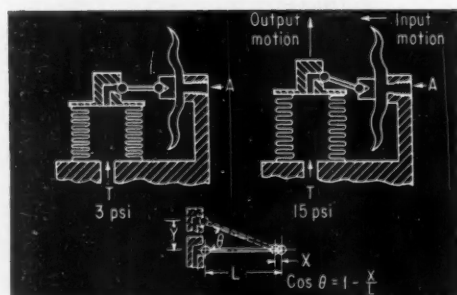
signal C to chamber A. Therefore, $C = A$ and

$$C = \frac{B \times D}{A} = \frac{B \times D}{C} = \sqrt{B \times D}$$

Thus, this computing unit can take the square root of the product of two variable signals, or of one variable multiplied by a constant.

Other square root extractors employ a geometric relationship as the operating principle—the change in cosine of an included angle compared with the change in the angle, a relationship that holds true for small angular displacement. Figure 8 shows such a unit. The signal whose square root is to be computed is input pressure A. The value of T is the square root of A. That is, $T = K \sqrt{A}$. The device works on a motion balance principle. Increasing input signal A moves the floating link to the left to restrict the pilot nozzle. The restricted nozzle increases the output pressure and moves the output feedback bellows upward until balance is restored. Since the length of the floating link is fixed, then $\cos \theta = 1 - (X/L)$. A plot of output displacement Y ($= \theta L$ for small values of θ , in radians) vs input displacement X shows the relationship to be virtually an exact square root.

FIG. 8. SQUARE ROOT EXTRACTOR.



H. FUNCTION GENERATING

Function generators produce any desired relationship between output and input signals. The relationship may be linear or nonlinear. Typical nonlinear functions arise from square root extracting, squaring, and taking the logarithm of the input signal. Since most pneumatic function generators are cam characterized, the devices can generate any function that can be cut on a cam and reproduced accurately by the cam follower. A characterized cam is particularly beneficial since the cam shape can be derived from test data supplied by a graph or table or from an analytically-derived equation defining a relationship between input and output.

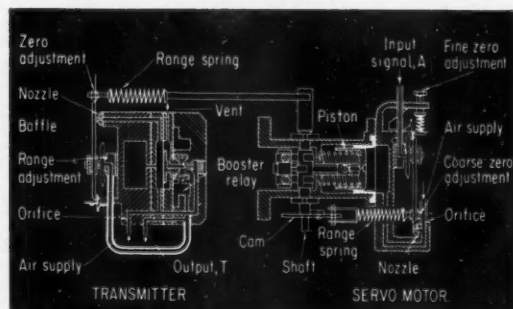


FIG. 9. FUNCTION GENERATOR.

The function generator in Figure 9 contains a cam-characterized servomotor and a linear force-balance transmitter. A change in input signal affects nozzle back pressure, moving the piston and rotating the cam shaft until the characterized cam

reaches a position where the resultant range-spring force balances the input force. The linear force transmitter provides an output proportional to the angular rotation of the shaft. The input-output relationship, therefore, follows the cam characteristic.

I. LOGIC FUNCTIONS

Four logic functions, AND, OR, NOT, and MEMORY, can be obtained with analog pneumatic computing units:

AND—The low pressure selector, Figure 10, provides the logic AND function. Here, output pressure *T* appears only when signal *A* and *B* are present at their input ports.

OR—High pressure selector, Figure 11, forms an OR unit. An output appears if either signal *A* or *B* is present.

NOT—The reverse acting high gain relay (on-off controller), Figure 12, provides the NOT function: an output signal is present when there is no input; if there is an input there will be no output. As the input signal acts on the bellows and overcomes the spring force, the pilot valve closes off the supply pressure and vents the output. With no input, the pilot valve permits the supply to pass to the output. (The same basic relay, with direct pilot action, forms a single-input AND unit.)

MEMORY—Figure 13 combines an OR unit and a single-input AND unit to provide memory. With input *A* at zero, there is no output *T*. When an input signal appears it is transmitted through the OR unit and actuates the single-input AND unit. Output *T* then appears, and through the action of the OR unit holds in the AND unit even if the original input disappears. The stored signal can be discharged by venting the feedback line.

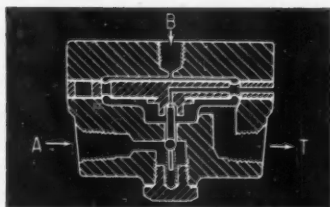


FIG. 10.
LOW
PRESSURE
SELECTOR.

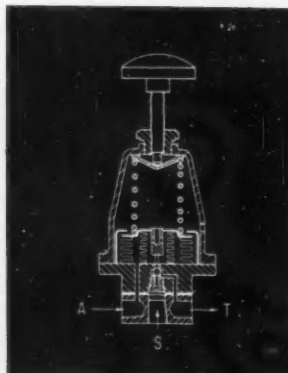


FIG. 12.
HIGH GAIN
RELAY.

FIG. 13. PNEUMATIC MEMORY.

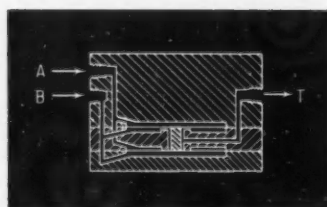
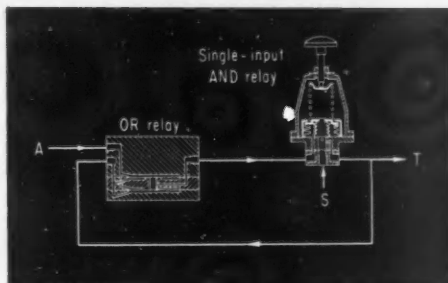


FIG. 11.
HIGH
PRESSURE
SELECTOR.

J. FUNCTION LIMITING

Often constraints must be placed on such variables as flow rate, temperature, and pressure. The relays in Figures 10 and 11 offer signal limiting. The low pressure selector, Figure 10, transmits the lesser of the two input signals. Therefore, for instance, when a pressure equivalent to the high limit of the variable is connected to input *A*, the output

will be that of input *B* unless it exceeds input *A*, in which case the output then equals the limit pressure *A*. Thus, the low pressure selector relay acts as a high limit relay.

The high-pressure relay, Figure 11, transmits the higher of the two input signals through the action of its dual differential diaphragm. As a function limiter, it forms a low limit relay.

USING PNEUMATIC ANALOG DEVICES FOR COMPUTING AND OPTIMIZING

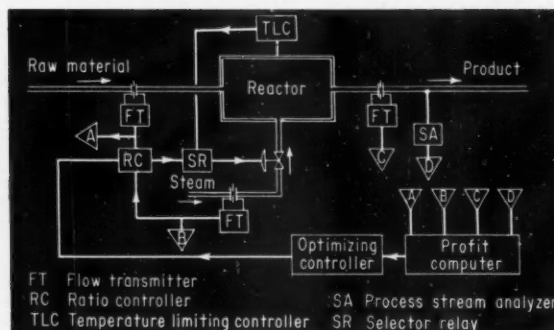


FIG. 14. REACTOR PNEUMATIC COMPUTING CONTROL.

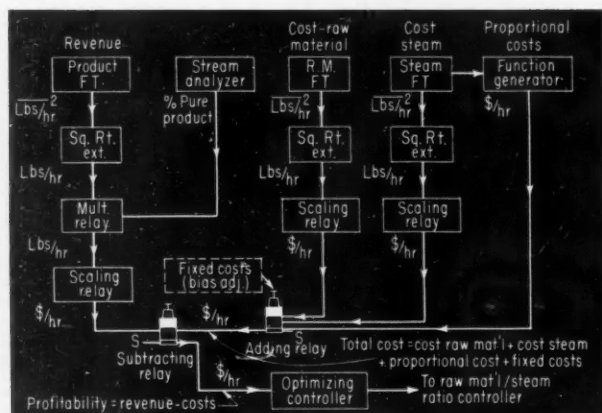


FIG. 15. PROFIT COMPUTER.

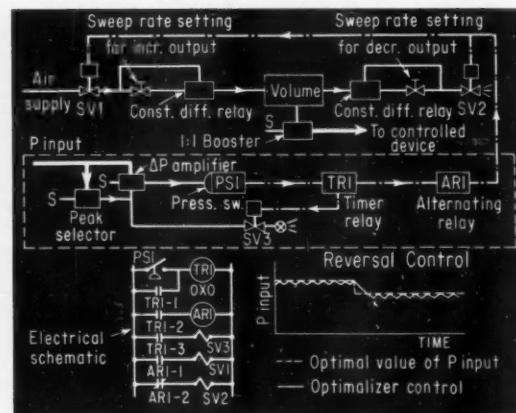


FIG. 16. CONTINUOUS SWEEP OPTIMIZING.

The chemical reactor in Figure 14 represents a process that can be operated for maximum profit by an optimizing and computing scheme employing many of the pneumatic analog devices described previously. Here, orifices meter raw material, steam, and product flows, and a stream analyzer measures percent product purity. Signals from these four variables are transmitted to a profit computer. The profit signal is the input to the optimizer controller whose output adjusts the setpoint of the ratio controller that fixes the necessary proportion of steam flow to raw material flow. The optimizer maintains profit at the maximum obtainable for existing operating conditions subject to a temperature limit constraint.

Figure 15 details the profit computer. Here,

$$\text{Profit} = \text{Revenue} - \text{Total cost}$$

Revenue is determined by taking the square root of the differential pressure signal representing product flow, multiplying this linearized flow signal by the signal from the stream analyzer (giving equivalent pounds of pure product), and scaling this over-all signal to convert it to dollars/hour. Likewise, total cost—as shown in the figure—is the sum of cost of raw material,

cost of steam, varying operating cost (a function of steam flow), and fixed operating cost. The cost-totalizing adding relay output signal and the revenue rate signal go to a subtracting relay which then computes dollars profit per hour. The profit signal is the input to the optimizing controller.

The operating point for maximum profit shifts with operating conditions. The optimizing controller, Figure 16, is one way of automatically manipulating the steam flow to raw material flow ratio to obtain the maximum profit determined by the profit computer for the existing conditions.

Optimizer operation is indicated by the plot in the figure. The output of the optimizing controller increases and decreases continuously at a constant sweep rate. Should the computed profit decrease, as shown, the optimizer output reverses to adjust the steam flow to raw material flow ratio.

The optimizer contains a volume chamber and a 1:1 booster relay, with a means for admitting air into the chamber to increase the pressure or out of it to decrease pressure. Reversal controls open either solenoid SV1 or SV2 to control direction of sweep, and the setting of the needle valves on the constant-differential-pressure

controllers determine sweep rate.

The peak selector in the reversal control section is a memory unit that stores the maximum signal value transmitted by the profit computer. This peak value becomes the reference against which a differential pressure switch continuously compares the peak with the existing profit value.

Suppose SV1 is open causing the optimizer output to increase which calls in turn for an increase in steam to raw material flow ratio. As long as the profitability keeps increasing, the optimizer keeps changing the ratio in this same direction.

Eventually, since a peak profit point exists, the ratio will increase so far that now the profit decreases. The pressure switch in the reversal section automatically senses the profit decrease and initiates reversal of the control action by closing SV1 and opening SV2. Because of reversal, the optimizer decreases the steam to raw material flow ratio and operation goes back in the direction of maximum profit. Thus the process hovers around the computed maximum profit.

Based on a presentation at the Sixteenth Annual Symposium on Instrumentation for the Process Industries, Texas A&M College, January, 1961.

How Much Torque from DC Dynamic Braking?

THE GIST: A squirrel-cage induction motor can be stopped by disconnecting the ac supply and applying dc to the stator windings. Current is induced in the rotor conductors as they cut the constant dc field and braking torque develops. To find out how long it will take to stop a given inertia it is necessary to know the variation of braking torque with speed for various values of dc excitation. The author shows how to calculate braking torque, using the standard induction motor equivalent circuit and a simple graphical technique, and confirms the method with tests on a typical induction motor.

ROBERT C. MOORE
Allis-Chalmers Manufacturing Co.

The driving and braking speed-torque curves for a squirrel-cage induction motor with dc dynamic braking are contrasted in Figure 1. When three-phase ac is applied to the stator windings in a normal manner, a rotating magnetic field is set up in the air gap. This rotating field cuts the rotor conductors, inducing current in these windings, and developing driving torque. Slip is maximum when the rotor is standing still and zero at synchronous speed. Driving torque increases with speed to a peak and then also decreases to zero at synchronous speed when the rotor and the rotating magnetic field are moving at the same speed.

In contrast, the speed-torque curve for dc dynamic braking is similar in shape but inverted with respect to speed. Direct current applied to the stator windings sets up a stationary magnetic field in the air gap with alternate north and south poles fixed in space around the periphery of the stator bore. Slip with respect to the stationary field is maximum when the rotor is turning at synchronous speed and decreases to zero as the rotor slows down and stops. Braking torque increases to a peak as speed decreases and then drops to zero at standstill. In the driven condition the ac stator current decreases with increasing speed, while in the braking mode the dc stator current is constant throughout the speed range.

Just as it is necessary to know the driving speed-torque curve to determine the accelerating characteristics of a motor-load combination, so it is necessary to know the braking torque curve to make sure that the braking characteristics meet specifica-

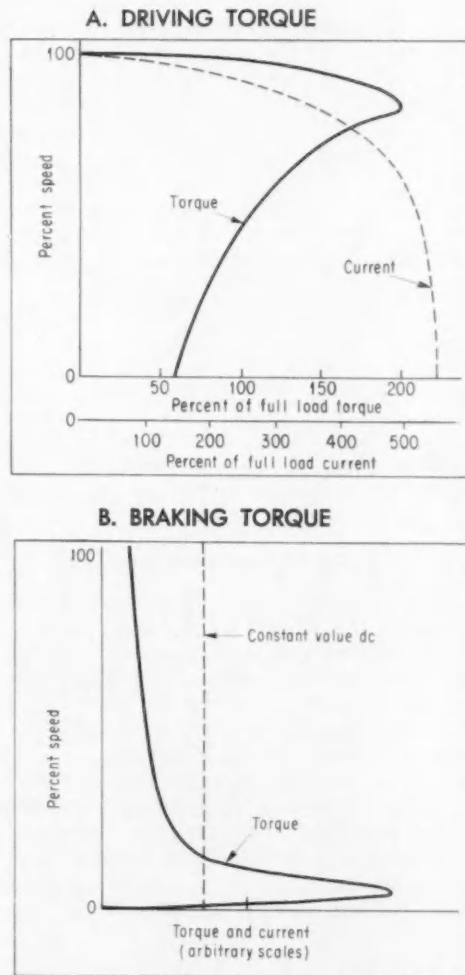


FIG. 1. Typical speed-torque-current curves for a squirrel-cage induction motor.

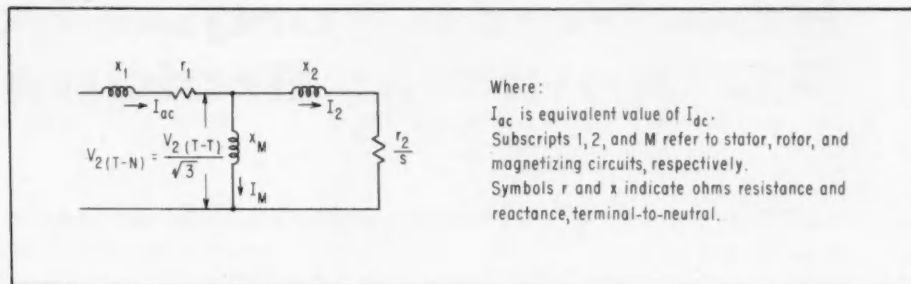


FIG. 2. Equivalent circuit is standard for polyphase induction motors.

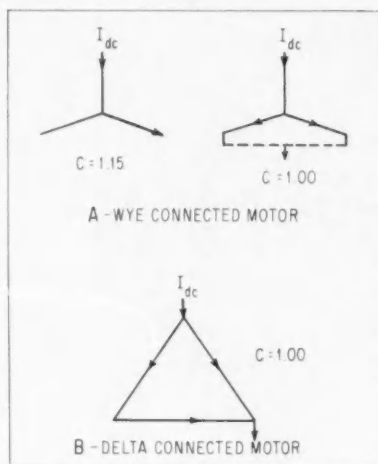


FIG. 3. Various ways of applying braking dc to wye or delta connected stator windings. C is defined in Equation 1.

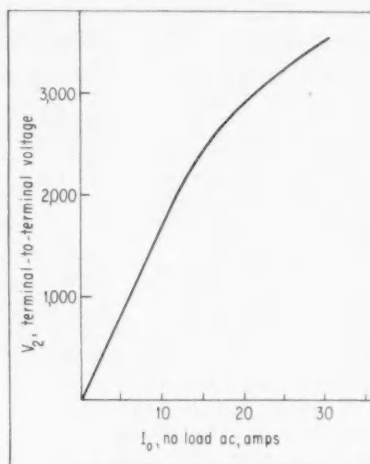


FIG. 4. Saturation curve for motor used in calculations. Variation of magnetizing reactance with terminal voltage causes deviation from a straight line.

tions. The following shows how to calculate the braking torque for various speeds and dc values using an equivalent circuit and graphical construction techniques.

Using the equivalent circuit for dc

The standard equivalent circuit of Figure 2 is normally used to calculate the driving speed-torque curves of polyphase induction motors operating on ac. Knowing the stator resistance and reactance (r_1 and x_1), rotor resistance and reactance (r_2 and x_2), and magnetizing reactance (x_M), the motor current, torque, and other variables can be calculated from the equivalent circuit for assumed values of slip and applied ac line voltage. But these are ac network calculations; to use the equivalent circuit to determine dynamic braking torque with dc excitation, the direct current I_{dc} must be expressed as an equivalent alternating current I_{ac} . Thus,

$$I_{ac} = \frac{CI_{dc}}{\sqrt{2}} \quad (1)$$

where the constant C depends on the method of connecting the stator winding to the dc supply. Figure 3 shows the various possibilities.

As expressed by Equation 1, a constant braking current I_{dc} yields a constant equivalent I_{ac} . The only way to keep I_{ac} constant when slip s is varied in the equivalent circuit is to vary the ac terminal voltage. But varying the ac voltage also varies the magnetizing reactance x_M . This problem is surmounted by using a no-load saturation curve for obtaining the proper value of x_M .

Thus, by expressing the dc braking current in equivalent ac terms and varying the ac terminal voltage to maintain a constant value of I_{ac} , the equivalent circuit of Figure 2 can be used for dynamic braking calculations.

An example shows how

To see how the technique works, consider the problem of determining the dc dynamic braking torque for a 157 hp, 1,200 rpm, 2,200 volt, 38 amps full load, three phase, 60 cycle, squirrel-cage induc-

tion motor. The calculated values of the motor constants needed for equivalent circuit computations are:

- $r_1 = 1.034$ ohms, stator resistance, terminal-to-neutral value
- $x_1 = 3.44$ ohms, stator reactance, terminal-to-neutral at 60 cycles
- $r_2 = 0.72$ ohms, rotor resistance, terminal-to-neutral in stator terms
- $x_2 = 3.46$ ohms, rotor reactance, terminal-to-neutral in stator terms at 60 cycles

As mentioned above, the magnetizing reactance x_M varies since it depends on the stator applied voltage. To determine the changing values of x_M under this condition, plot a no-load, three phase, 60 cycle saturation curve by running the motor at no load, 60 cycles and measuring motor current for different values of applied ac voltage. For each voltage applied during the test the stator reactance drop may be arithmetically subtracted:

$$V - \sqrt{3} I_o x_1 = V_2 \text{ terminal-to-terminal volts}$$

where V = applied ac voltage, terminal-to-terminal

I_o = current with voltage V applied

$V_2 = \sqrt{3}$ times voltage across x_M of equivalent circuit

The saturation curve shown in Figure 4 is then obtained by plotting V_2 vs I_o for the motor under consideration. Magnetizing reactance x_M can be graphically calculated from this curve.

To carry through a typical calculation, determine the braking torque at 24 rpm, with a dc braking current of 47 amps applied to the stator windings in the two terminal wye configuration of Figure 3A ($C = 1.15$). The equivalent alternating current from Equation 1 is

$$I_{ac} = \frac{1.15(47)}{\sqrt{2}} = 38.2 \text{ amps}$$

and the slip referred to synchronous speed is 24/1,200, or 0.02.

According to the equivalent circuit of Figure 2, the circuit current I_{ac} is the vector sum of the magnetizing and rotor currents,

$$I_{ac} = I_2 + I_M \text{ (vector sum)} \quad (2)$$

and the current in each branch circuit can be expressed as follows:

$$\text{Magnetizing circuit current} = I_M = \frac{V_2}{j\sqrt{3}x_M} \quad (3)$$

so that I_M lags V_2 by 90 deg ($I_M \angle 90^\circ$);

$$\text{Rotor circuit current} = I_2 = \frac{V_2}{\sqrt{3}Z_2} \quad (4)$$

where Z_2 = rotor impedance in ohms

$$Z_2 = r_2/s - jx_2 = 36 - j3.46$$

so that I_2 lags V_2 by the phase angle between r_2/s and x_2 , in this case 5.5 deg ($I_2 \angle 5.5^\circ$).

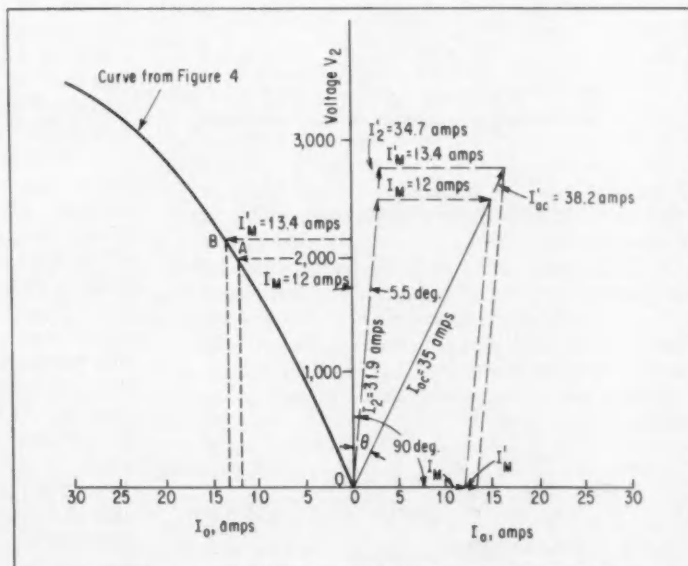
From Equation 2, the vector sum of the two branch circuit currents is

$$I_{ac} = I_2 \angle 5.5^\circ - I_M \angle 90^\circ = 38.2 \angle \theta$$

By redrawing the curve of Figure 4, as shown in Figure 5, the vector addition can be done graphically in the following manner:

1. Assume any value of V_2 , say 2,000 volts. For this value the magnetizing current at point A on the curve in Figure 5 is $I_M = 12$ amps. Plot I_M on the horizontal axis of Figure 5, lagging V_2 by 90 deg as required by Equation 3. Now calculate the rotor current for $V_2 = 2,000$ volts from Equation 4 and plot the result $I_2 = 31.9$ amps, lagging V_2 by 5.5 deg. Add I_M and I_2 graphically to obtain a value of $I_{ac} = 35$ amps. This is smaller than the

FIG. 5. Graphical step in calculation of dynamic braking torque. Availability of no-load saturation curve and the use of vector addition makes it easy to successively approximate correct value of I_{ac} . Usually two steps are sufficient.



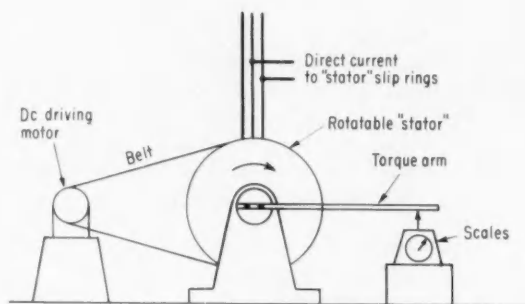


FIG. 6. Test for measuring dynamic braking torque uses special motor.

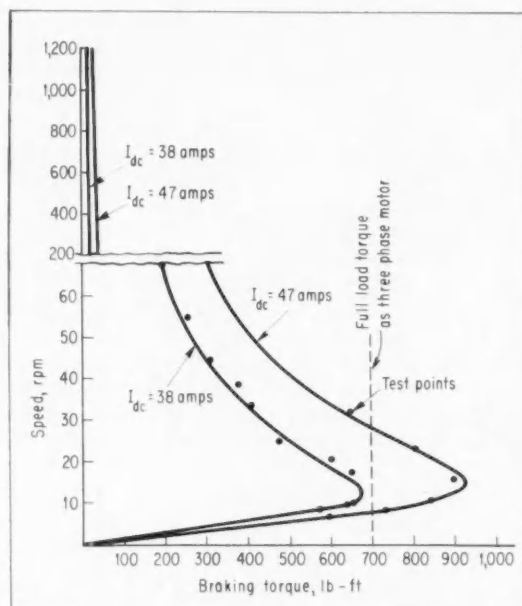


FIG. 7. Correspondence of calculated curve and test-obtained points shows accuracy of method.

required value of 38.2, so a larger value of V_2 must be assumed.

2. Try a value of $V_2 = 2,175$ volts. Now I_M' is read from the curve as 13.4 amps and rotor current I_2' is calculated from Equation 4 to be 34.7 amps. Plotting these at the proper phase angles and adding graphically gives the desired I_{ac}' of 38.2 amps.

Braking torque can then be calculated from the following expression:

$$T = \frac{21.1 I_2'^2 r_2 / s}{N_s} \text{ lb-ft} \quad (5)$$

where N_s = synchronous speed, so that, for this case,

$$T = \frac{21.1 (34.7)^2 (36)}{1,200} = 760 \text{ lb-ft}$$

The same procedure can be followed to determine braking torques for other speeds and for other values of dc braking current.

Approximate values of I_2 can be obtained by extrapolating I_{ac} to the correct value after the first try and graphically subtracting an approximate value of I_M from I_{ac} . The accuracy of this approximation depends on the closeness of the first try and the amount of variation of x_M (or, in other words, the deviation of the saturation curve from zero-based linearity up to the point of interest).

Tests confirm calculations

To check the accuracy of the calculations, tests were run on a special version of the motor considered here. Electrically the test motor was the same, but mechanically it was constructed with a rotating "stator" having its own bearings and slip rings to conduct current to the stator windings. For dynamic braking torque tests the stator was belt driven by a separate dc motor, Figure 6. Thus, the stator was driven at the proper speed (for the previous calculations, 24 rpm) while the torque arm on the rotor and the scale held the rotor at standstill and measured the braking torque.

Calculated and test-obtained data are compared in Figure 7 for dc braking currents of 47 and 38 amps. The curves obtained by calculation and the points obtained by test show a close correspondence.

Factors influencing stopping time

Reduced stopping time can be achieved by reducing the inertia of the rotating parts or by increasing the braking torque. In some cases, inertia can be decreased by improving the mechanical drive system beyond the motor or by using high temperature rated motors or motors designed specifically for low inertia and high response. But if inertia is fixed, only increased braking torque will help.

Up to a certain point, dynamic braking torque increases with an increase in dc excitation to the stator. However, large values of dc may be accompanied by high magnetic saturation in the motor, appreciably decreasing the magnetizing reactance x_M and shunting a large proportion of the dynamic braking current through the magnetizing branch circuit of Figure 2. Therefore, large values of dc may not produce a significant increase in braking torque.

An important factor that must not be overlooked is the time required to switch from ac to dc. A 600 rpm induction motor will rotate five revolutions if control transfer from ac to dc takes a 30 cycle interval. If the motor and drive must stop in nine revolutions, then dynamic braking must stop the inertia in four. If the transfer time is reduced to 15 cycles, the motor only rotates $2\frac{1}{2}$ revolutions and the dynamic braking allowance is raised to 6 $\frac{1}{2}$ revolutions. Therefore, it is evident that minimizing transfer time is a must.

How Industry Sees Microminiaturization

A company surveyed a cross section of industry to sample reactions to 16 techniques for microminiaturization. The replies foresee phenomenal growth for both modular and molecular techniques. The sampling attempts to determine preferences based on such factors as:

- Inherent reliability
- Inherent design flexibility
- Practicality with regard to cost
- Adaptability to automatic production

The author also estimates when these techniques will have their greatest impact.

S. M. STUHLBARG
P. R. Mallory & Co., Inc.

TABLE I
MICROMINIATURIZATION TECHNIQUES*

NAME	SUPPLIER	STATUS
HIGH DENSITY PACKAGING TECHNIQUES		
1. AMP MECA	AMP, Inc.	Commercial production
2. Macro-Module	Burroughs Corp.	Engineering samples
3. Cordwood technique		
Weld Paks	Raytheon Mfg. Co.	Commercial production
Dice	Republic Aircraft Corp.	
MiniWeld	Francis Associates with Sippican Corp.	
(No trade name)	Bendix Corp. (Radio Div.)	
(No trade name)	Litton Industries	
MICROMODULES		
4. Micromodule system	RCA	R&D
5. TIMM system	General Electric	R&D
6. Microelectronics (dot circuitry)	Semiconductor Div. Hughes Aircraft	R&D
7. UCA technique	P. R. Mallory Co.	Resistors and capacitors commercially available
8. Microminiature modules	Sylvania Products Corp.	R&D
9. Ceramic-based microcircuits	Sprague Electric Co.	R&D
10. MICRAM	Cleveland Metal Specialties, Inc.	Military production
11. Microcircuits	Hi Q Div., Aerovox Corp.	R&D
12. Mu circuitry	International Resistance Co.	Commercial production of NOR unit, others R&D
13. Thin film technique	Varo Mfg. Co.; Motorola; Servomechanisms; IBM	R&D
INTEGRATED CIRCUITS		
14. Solid circuits	Texas Instruments	Commercial production
15. SemiNets (micrologic)	Fairchild Semiconductor Corp.	R&D
16. Molecular electronics	Westinghouse	R&D
		Engineering samples available of 18 functions

*Not a complete listing. Techniques are those included in the author's survey.

There is little question that microminiaturization will play a large role in the expanding electronics market during the next 10 years. To determine how large this role might be, The P. R. Mallory Co. sent a questionnaire to over 300 companies asking their views on some key questions about microminiaturization. Ninety-eight of the companies replied. In addition, 250 engineers, scientists, purchasing agents, and marketing analysts working in miniaturization were questioned in person. From this study the following predictions can be made:

1. By 1965, the microminiaturization market will expand by a factor of 10, to an estimated \$120 million per year.

2. By 1980 the market for molecular electronics will expand to an estimated \$14 billion—representing 85 percent of the total microminiaturization market.

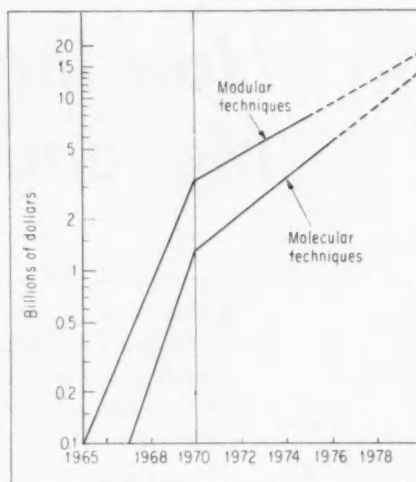
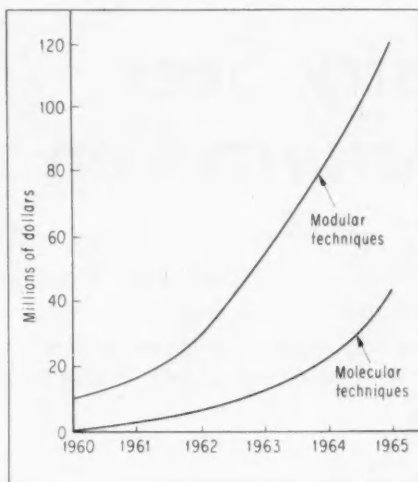
3. By 1970 military applications will account for 55 percent of the microminiaturization market; commercial applications—industrial and consumer—will use the remainder. Twenty percent of all electronic equipment will be miniaturized by 1970.

4. The greatest potential for inherent reliability is possessed by the technique that incorporates a circuit function in semiconductor material, such as molecular electronics.

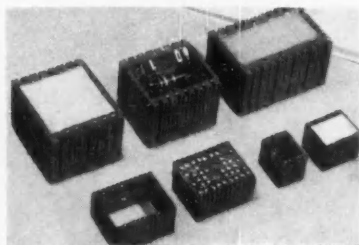
5. Most inherent design flexibility is possessed by that high density packaging technique in which components are packaged as standard pellets and then inserted in the proper holes of a circuit board.

6. The miniaturization technique with the great-

GUIDE TO MARKETS

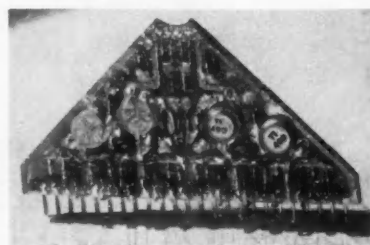


GUIDE TO 16 MICROMINIATURIZATION TECHNIQUES



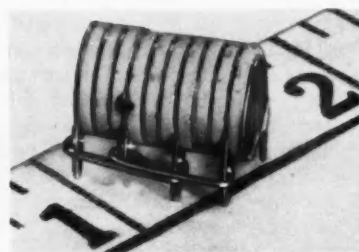
1. AMP MECA SYSTEM

A technique for high density packaging of conventional components, or so-called integrated circuits (see techniques no. 14 to 16); its name comes from Maintainable Electronic Component Assemblies, and subassemblies built this way are said to allow component maintenance. Components, circuits, or devices are stacked vertically in plastic cells which are built into subassemblies with plastic programmed circuit boards. Each cell has two ribbed sides; each side contains one spring contact that has two points of contact, at the top and at the bottom—a total of four contacts per cell. Two parallel programmed circuit boards—each can carry as many as nine conductor lines—and spacers form rigid three dimensional structure to house cells. Rib contacts inserted at proper locations connect cells to form subassembly. Supplier: AMP Inc., Harrisburg, Pa. Status: commercially available.



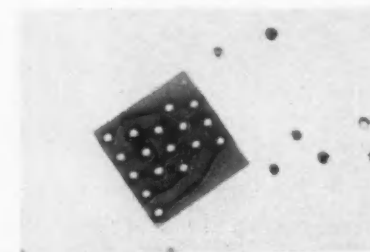
2. BURROUGHS MACRO-MODULE

A high density packaging technique in which circuits are mounted on triangular plastic chips which have 24 pins along one edge for connection. The circuit laden chips are inserted, one behind the other, into a plastic or metal sleeve which is then filled with an encapsulant. To assemble a subsystem, four sleeves are placed side by side, hinged, and then folded to form a rectangular box. Using microcomponents, Burroughs has mounted two flip-flops, containing 54 components, on a single chip, is currently building an airborne digital differential analyzer with 3,000 components (averaging 32 components per chip). Supplier: Burroughs Corp. Research Laboratories, Paoli, Pa. Status: demonstrating feasibility.



5. GE TIMM SYSTEM

The TIMM (Thermionic Integrated Micromodule) package relies on small heaterless vacuum tubes. Components (including vacuum tube diodes and triodes) are made as discs or rings from ceramic, titanium, and carbon, and stacked into a cylindrical package. The cylinder is exhausted and the vacuum sealed in. There are no heater circuits; components generate enough heat to sustain tube operation. Components have high resistance to nuclear radiation. Supplier: G.E. Status: R&D.



6. HUGHES MICROELECTRONICS

Components such as diodes, transistors, resistors, and capacitors are packaged into tiny standardized cans of 0.050 in. in diam and 0.030 in. high. The cans are mounted on a Fotoceram circuit board, perforated according to a drawing. One problem still to be solved is the development of leadless components. Experimental diodes and transistors have been built. Supplier: Hughes Aircraft. Status: research.

est capability of being used, considering cost versus reliability, is the cordwood technique in which components are stacked horizontally like firewood.

7. Most useful technique:

in 1960-1965	cordwood technique
in 1965-1970	thin films
in 1970-1975	molecular electronics

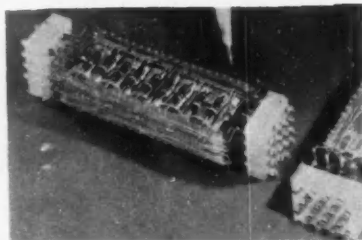
For the purposes of this survey, only 16 miniaturization techniques were considered: those listed in Table I and described in the Guide to Miniaturization Techniques below. This list is not all-inclusive; modification of some of these techniques have been proposed and are under evaluation. In this survey, the companies were asked about the specific techniques rather than a group or classification of

techniques, because it has been difficult to organize the approaches to miniaturization in categories.

A rough classification with some validity does emerge from this study: what might be called modular techniques versus molecular electronic ones. Molecular electronic techniques are those in which an integrated circuit or junction is built into a single piece of material or a crystal. Modular techniques include high density packaging and micromodule techniques. Molecular electronics seems the most promising technique.

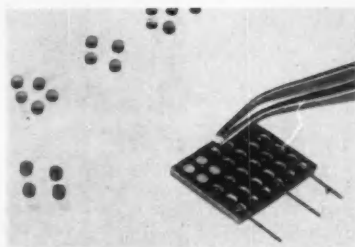
Market estimates

One main purpose of the study was to estimate the potential market for microminiaturization. The



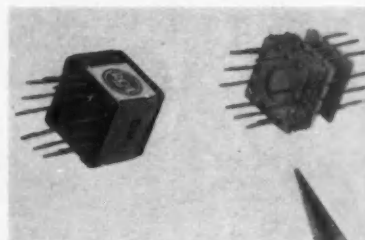
3. CORDWOOD TECHNIQUE

A method of assembling components in which the components are stacked side by side (like cordwood) between printed circuit boards to increase the density through a reduction of the volume required for interconnection. The method is frequently limited to a component whose leads run parallel to its axes. The leads are soldered or welded to printed wiring or ribbon leads attached to the base material. Welding, particularly resistance welding, appears to be gaining popularity to make connections because the short heating cycle does not damage closely packed components. Suppliers: Raytheon Mfg. Co. (Weld Paks), Waltham, Mass.; Bendix Corp., Radio Div., Baltimore, Md.; Republic Aviation Corp. (Dice), Farmingdale, Long Island, N. Y.; Francis Associates and Sippican Corp. (MiniWeld), Marion, Mass.; Litton Industries, Monrovia, Calif. Status: in production, available commercially.



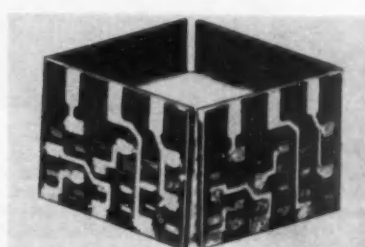
7. MALLORY'S UCA TECHNIQUE

A somewhat similar approach to Hughes Microelectronics, Mallory's Unitized Component Assembly uses components in the form of pellets 0.100 to 0.0250 in. in diameter and about 1/16 in. thick. These plug into holes in a 1/16 in. thick circuit board. Units available to date include resistors, capacitors, and silicon rectifiers. Supplier: P. R. Mallory & Co. Inc., Indianapolis 6, Ind. Status: engineering samples available.



4. RCA MICROMODULE SYSTEM

One or more components deposited or mounted on a square ceramic wafer, called a microelement, 0.020 in. on a side and about 0.01 in. thick. Each edge of the square has three notches which are metallized with solder pads attached for connection. To build a subassembly, several microelements are stacked one on top of another, with connection made by soldering riser wires to the solder pad of the wafers. The stacked system is encapsulated. Microelements developed to date include resistors (10 to 100 kilohms), capacitors, inductors, transistors, and diodes. Supplier: RCA is prime contractor for a Signal Corps project that involves a large number of participating companies. Status: in research and development stage.



8. SYLVANIA MICROMINIATURE MODULES

Microminiature components are mounted on the surface of a ceramic wafer 0.440 in. square and 0.010 in. thick. Subsystems and systems are put together by stacking wafers. Objective: a complete function on each ceramic wafer. Each wafer has three tabs on each side. End tabs fit into slits on vertical interconnection boards with painted conductor circuits. No internal wiring. Supplier: Sylvania Electric Products, General Telephone and Telegraph Corp. Status: digital circuits demonstrated.

curves on page 116 tell the story of tremendous predicted growth. The market should increase tenfold by 1965, 30 times by 1970—and these reflect conservative estimates. The total microminiaturization market should reach \$120 million by 1965. Of this amount, about \$100 million will be modular techniques, the rest molecular electronics.

From 1960 to 1965, the market for molecular techniques will be composed primarily of thin film circuitry built for precision military equipment. Growth will be slowed by the high investment required to develop and apply the new design concepts. By 1965, molecular techniques will represent about 18 percent of the total market.

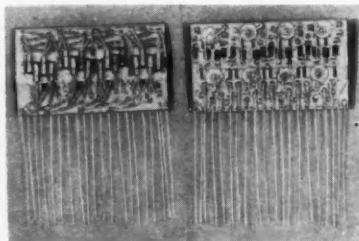
Many equipment manufacturers consider the

modular technique as an interim solution which eventually will be discarded as molecular techniques become practical. Hybrid approaches are also tolerated as a temporary measure. By 1970, however, the major microminiaturization market will be devoted to thin film techniques and semiconductor

TABLE II
GROWTH OF MICROMINIATURIZATION
(Billions of Dollars)

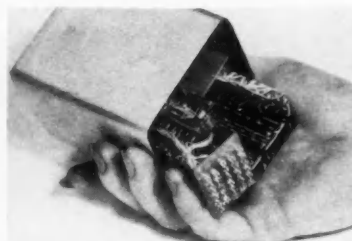
	1960	1965	1970	1980
The electronics industry.....	\$10	\$15	\$20	\$40
Electronic equipment subject to microminiaturization.....	\$ 5	\$10	\$15	\$30
The microminiaturization market.....	\$ 0.01	\$ 0.12	\$ 1.5 to \$5	\$25
Percentage of equipment microminiaturized —	—	1 to 5	20	85

GUIDE TO 16 MICROMINIATURIZATION TECHNIQUES (Cont.)



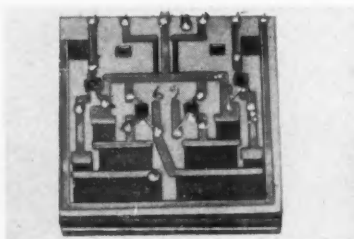
9. SPRAGUE CERAMIC BASED MICROCIRCUITS

On a ceramic base, into which cavities are cut for uncased semiconductors, Sprague puts a complete circuit or group of stages. As many as 120 components have been included on a single 2.0×3.7 in. wafer. The ceramic also serves as capacitor dielectric; resistance is provided by screened resistors. Supplier: Sprague Electric Co., No. Adams, Mass. Status: prototype demonstrated.



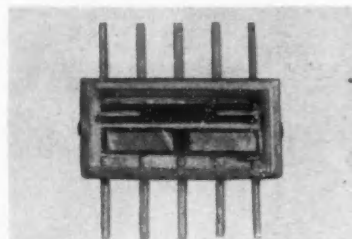
10. MICRAM

Name stands for Microminiature Individual Component Reliable Assembled Modules. Standard miniaturized components are soldered to ceramic wafers $\frac{1}{2}$ in. square. Interconnections are made by printed wiring or fired lines. Supplier: Cleveland Metal Specialties Co., coordinating this program as a joint venture, including Aerovox Corp., Pacific Semiconductors, Inc., Raytheon Co., Formica Corp., Welrite Products, Inc., and Sylvania Electric Products, Inc. Status: modules are being produced for infrared devices, electronic timing, and fuzing systems for the U. S. Army.



13. THIN FILM TECHNIQUE

Metal films are sputtered or vacuum evaporated in Angstrom thicknesses to form conductors, resistors, and/or capacitors. Active components such as transistors are added as separate elements. Big potential lies in ability to deposit multiple layers on a single substrate, but only low voltage circuits can be employed this way at present because of heat dissipation problems. Varo Mfg. Co. has built a thin film circuit package with 104 components, containing four high speed flip-flop circuits in a 0.125 cu in. space. Eventually expect to deposit semiconductor active devices. Suppliers: Varo Mfg. Co.; IBM; Motorola; Servomechanisms, Inc.



14. TI SOLID CIRCUITS

A circuit is made in a block of silicon, $\frac{1}{4}$ in. square \times $\frac{1}{8}$ in. thick by diffusing resistors, mesa transistors, diode function and other components. A reverse-biased PN junction serves as a capacitor, with the depletion region of the junction acting as the dielectric. Inductance cannot be made this way; application has been limited to date to equipments such as flip-flops or multivibrators that need no inductance. Supplier: Texas Instruments. Status: commercial availability of binary flip-flop; other devices under R&D. (Others working along similar lines: RCA, U. S. Army Diamond Ordnance Fuze Laboratory, and Royal Radar Establishment, England.)

processing. While the total market for microminiaturization grows to \$2 billion by 1970 and \$5 billion by 1980, the share devoted to molecular electronics should grow from 40 percent in 1970 to 55 percent by 1975 and to 75 percent by 1980.

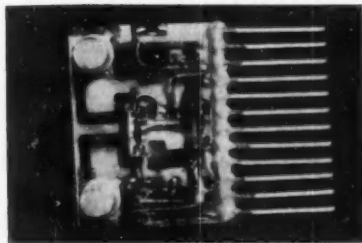
The percentage of microminiaturized equipment is also likely to mushroom. Although it is estimated that only one to five percent of all equipment will be microminiaturized by 1965, the percentage is expected to grow to 85 percent by 1980. Table II summarizes the estimated growth of the electronics industry and microminiaturization.

In 1970 major users of microminiaturization are likely to be suppliers of airborne electronics, missile electronics, computers, space electronics, and com-

munications. It is expected that by 1970 military electronic expenditures will double and the market for industrial electronics quadruple—growth that will increase the opportunities for microminiaturization.

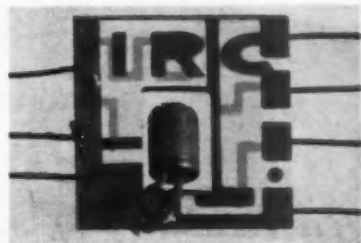
Technique preferences

Each interviewee was asked to answer seven questions about microminiaturization, rating his preferences on the basis of first choice, second choice, up to as many as 11 choices. To evaluate the replies, points were assigned to each choice. A first choice earned 11 points, a second earned 10, down to a last choice that earned a single point. The users answered some interesting questions, which are reported on page 120.



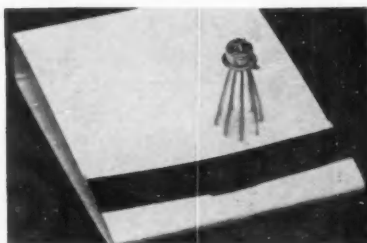
11. MICROCIRCUITS

Microminiature components, including screened resistors, are mounted on $1 \times \frac{3}{4}$ in. steatite plates. To form a sub-assembly, the wafers are mounted perpendicular to a base plate. A full adder, containing 85 components in a $0.5 \times 0.625 \times 1.0$ in. package has been built. Supplier: Hi-Q Div., Aerovox Corp. Status: research and development.



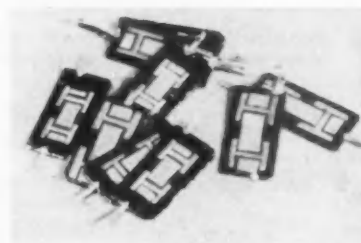
12. Mu CIRCUITRY

Passive units such as resistors are deposited as thin films on a 0.4 in. square glass plate, 0.050 in. thick. First unit commercially available was a transistor NOR unit (price: \$46) made with a conventional transistor. Techniques can employ micro transistors. Supplier: International Resistor Co. Status: commercial production of NOR units; others are still in R&D.



15. FAIRCHILD MICROLOGIC ELEMENTS (SemiNets)

Flip-flops, gates, adders, shift registers, and buffers are produced on single silicon substrates by diffusion, evaporation, and photo lithographic techniques. The digital devices are then packaged in 8-lead transistor cans—T0-5 and T0-18. Supplier: Fairchild Semiconductor Corp. Status: prototypes have been tested, engineering samples of NOR units available.



16. WESTINGHOUSE MOLECULAR ELECTRONICS

One piece systems or subsystems. Properties of a single crystal are modified to achieve a given transfer function. Conventional circuit-concepts cannot be translated into these devices; designers do not think in terms of resistance, capacitance, and inductance. Westinghouse has developed 18 different types of functional blocks using three basic structures: alloyed structures, base diffused structures, and double-diffused oxide-mask structures. Supplier: Westinghouse Electric Corp. Status: engineering samples of the 18 functional blocks are available; R&D. Others working along similar lines include RCA with its Unipolar transistor; Sperry Semiconductor Div. with inverters, NOR circuits, and flip-flops; and Varo Mfg. Co.

HOW INDUSTRY CHOOSES

Q. Which technique do you prefer on the basis of inherent reliability?

Ans.	STANDING	TECHNIQUE	NO. OF 1st PLACE VOTES
	1	TI solid state circuits	14
	2	Westinghouse molecular electronics	21
	3	Cordwood technique	13
	4	Thin film technique	7
	5	Solid state micrologic units	7
	6	RCA micromodule system	2

Q. Which technique do you prefer on the basis of inherent design flexibility?

Ans.	STANDING	TECHNIQUE	NO. OF 1st PLACE VOTES
	1	Cordwood technique	33
	2	Mallory UCA technique	8
	3	Hughes dot circuitry	15
	4	RCA micromodule	5
	5	MICRAM	7
	6	Thin film technique	6

Q. Which technique do you prefer on the basis of practicability with regard to cost versus reliability?

Ans.	STANDING	TECHNIQUE	NO. OF 1st PLACE VOTES
	1	Cordwood technique	22
	2	Mallory UCA technique	13
	3	RCA micromodule system	9
	4	Hughes dot circuitry	10
	5	Aerovox microcircuits	9
	6	Thin film technique	4

Q. How do you rank the various methods with respect to adaptability for automatic production?

Ans.	STANDING	TECHNIQUE	NO. OF 1st PLACE VOTES
	1	RCA micromodule system	7
	2	Mallory UCA technique	3
	3	Thin film technique	9
	4	Hughes dot circuitry	10
	5	TI solid state circuits	7
	6	Fairchild solid state micrologic elements	6

Q. How do you rank the various methods with respect to capability of interconnecting individual components and/or circuit modules?

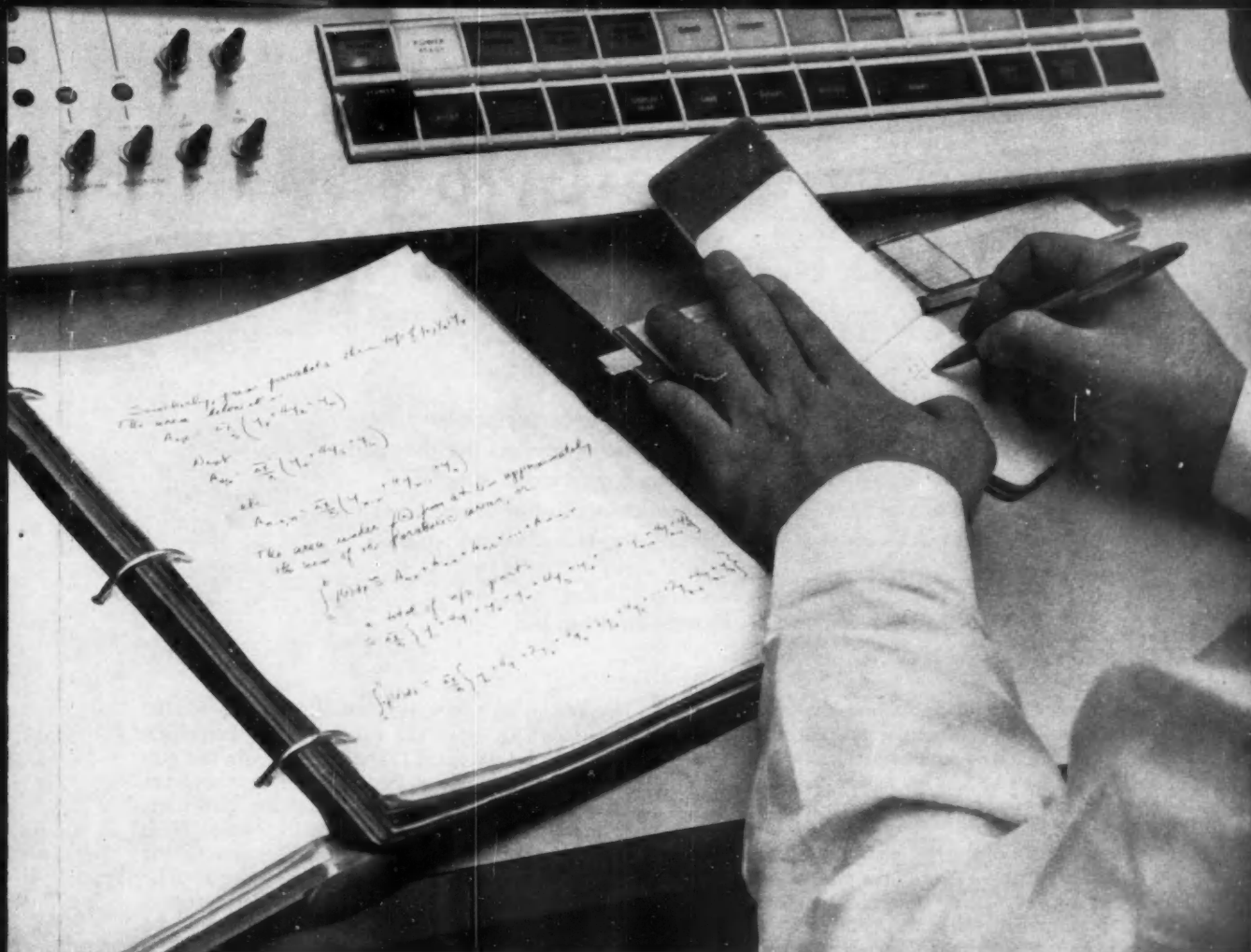
Ans.	STANDING	TECHNIQUE	NO. OF 1st PLACE VOTES
	1	Cordwood technique	25
	2	Mallory UCA technique	7
	3	Hughes dot circuitry	8
	4	RCA micromodule system	3
	5	TI solid state circuits	6
	6	Thin film technique	8

Q. Which technique do you prefer on the basis of practicability to form completed equipments, particularly considering heat dissipation?

Ans.	STANDING	TECHNIQUE	NO. OF 1st PLACE VOTES
	1	Cordwood technique	12
	2	Mallory UCA technique	10
	3	Hughes dot circuitry	9
	4	Burroughs Macro-Module	11
	5	RCA micromodule system	7
	6	Thin film technique	9

Q. How do you rank these techniques on over-all usefulness to your company during the four time periods indicated?

Ans.	STANDING	1960-'61	1962-'65	1965-'70	1970-'75
	1	Cordwood technique	Cordwood technique	Thin film technique	Molecular electronics
	2	Mallory UCA technique	Hughes dot circuitry	Molecular electronics	TI solid state circuits
	3	Hughes dot circuitry	Mallory UCA technique	TI solid state circuits	Thin film technique
	4	RCA micromodule system	Thin film technique	Fairchild solid state micrologic elements	Fairchild solid state micrologic elements
	5	Thin film technique	TI solid state circuits	Hughes dot circuitry	Hughes dot circuitry
	6	AMP MECA systems	RCA micromodule system	Mallory UCA technique	IRC Mu circuitry
	7	IRC Mu circuitry	IRC Mu circuitry	RCA micromodule system	Cordwood technique
	8	MICRAM	Fairchild solid state micrologic elements	IRC Mu circuitry	RCA micromodule system
	9	TI solid state circuits	MICRAM	Cordwood technique	Mallory UCA technique
	10	Aerovox microcircuits	Sylvania microminiature modules	Sprague ceramic-based microcircuits	GE TIMM system



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Two vs Three-Gyro Guidance Platforms-II

SERVO SYSTEM DYNAMICS

THE GIST: In this second half of his article on gyro platforms for inertial guidance applications, author Fischel reviews the dynamics of the servo systems associated with each gyro axis. He also discusses angular oscillations as an additional error source, and tabulates the major differences in instrumenting the two platform types.

E. M. FISCHEL, Kearfott Div., General Precision, Inc.

In the first part of this article the two principal types of guidance platforms were compared, and the responses of each to various accelerations and mass shifts were tabulated. This second part takes a look at the servo systems used with each type and the dynamics involved.

Servo systems of the two platform types are shown in Figure 1. Table I defines the symbols used. Both systems consist of the same chain of components, viz., preamplifier (K_1); demodulator, lead-lag networks, and modulator (N); power amplifier (K_2); and torque motor (T_M) with its gear box. A highly sensitive inductive type of pickoff attached to the gimbal of each gyro generates the error signal.

In the servo loop, the error signal is amplified, demodulated, and then fed to the compensating networks where the correct phase and amplitude relationship, over the necessary frequency range, is established. It is then remodulated, further amplified, and applied to the torque motor which delivers its torque through the gearing to the gimbal frame. The loop is closed as this torque nulls out the error signal. At this point, the two systems differ widely.

In the two-degree-of-freedom arrangement used on the two-gyro platform, the gyro is completely isolated from the gimbal frame. Any deviation of this frame with respect to the gyro's gimbal is sensed by the corresponding pickoff and transmitted as an error signal. It is amplified and fed to the torque motor, whose torque accelerates the gimbal frame in a direction to reduce the error and bring the two gimbals back into coincidence. As may be seen in Figure 1B, the dynamics of the gyro are not involved in the loop. The gyro provides a reference attitude only, but does not contribute anything to the stabilization torque of the system.

In the three-gyro platform each single-degree-of-

freedom gyro is mounted directly on the gimbal frame with its input axis parallel to the frame axis that is to be stabilized (Figure 1A). Only the output axis of the gyro is free. Therefore, under the effect of an arbitrary inserted torque the gyro starts to precess to prevent deviation of the frame. This effect can be considered a prestabilization of the frame by the gyros, without the servo system. The deviation of the frame could be considered zero if the damping around the precession axis could be kept to zero and if the disturbing torque could be kept small enough or the angular momentum large enough to prevent the gyro from precessing beyond its limits. This, of course, is not possible. The frame deviates slightly and the gyro reaches the stops of its output axis. Consequently, a servo system that operates on the error signal obtained from the precession angle of the gyro is required. This signal is fed to the torque motor which torques the gimbal and causes the gyro to precess back to its zero position. The interaction of the gyro with the servo system can be seen in the block diagram of Figure 1A. The system has a major and minor loop with the latter closed around the gyro.

SYSTEM DYNAMICS

Behavior of the servo systems will be described by means of their differential equations and transfer functions. These are set up on the basis of the schematic and block diagrams in Figure 1. They have been linearized, and the terms for coulomb friction, backlash, nonlinear amplifiers, etc., have been neglected. In a design analysis, however, these must be taken into account.

Servo system for three-gyro platform

The torques around the ϕ and ψ axes are given by

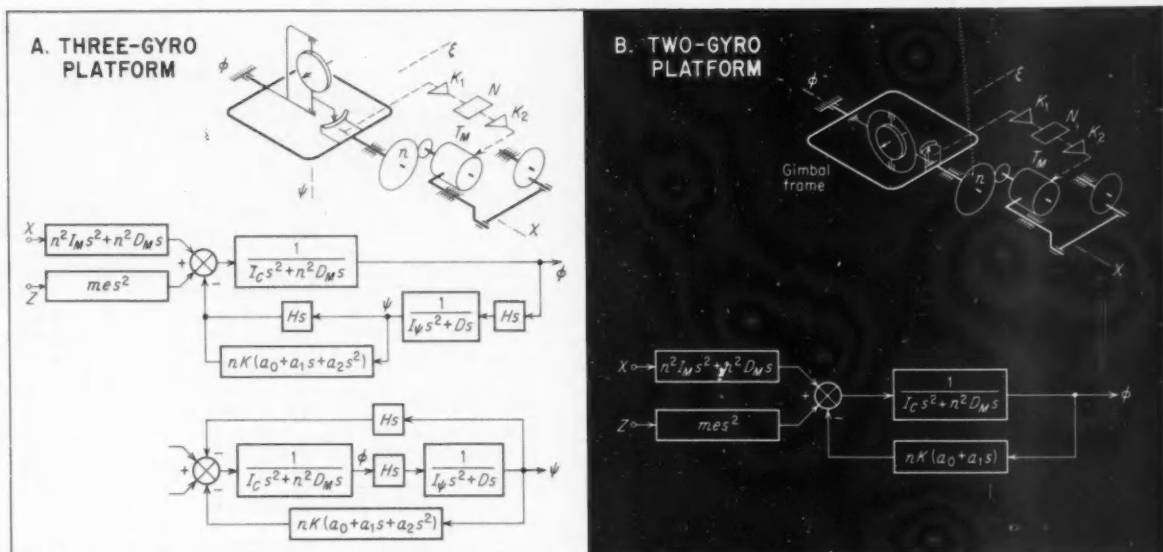


FIG. 1. Servo system and block diagram for a single axis of the two types of platforms.

$$I_{\phi} \frac{d^2 \phi}{dt^2} + n^2 I_M \left(\frac{d^2 \phi}{dt^2} - \frac{d^2 \chi}{dt^2} \right) + n^2 D_M \left(\frac{d\phi}{dt} - \frac{d\chi}{dt} \right) + H \frac{d\psi}{dt} + T_M = me \frac{d^2 z}{dt^2} \quad (1)$$

$$\text{and} \quad I_{\psi} \frac{d^2 \psi}{dt^2} + D \frac{d\psi}{dt} - H \frac{d\phi}{dt} = 0 \quad (2)$$

A simplified equation governing the torque motor is

$$nK \left(a_0 \psi + a_1 \frac{d\psi}{dt} + a_2 \frac{d^2 \psi}{dt^2} \right) = T_M \quad (3)$$

This simplification should be justified since it is applied to both systems. The complete function would include expressions for the demodulator, modulator, and the lead-lag networks, which are used in the actual system. Inclusion of these items, however, would extend the investigation unnecessarily, since the networks can be designed to perform in accordance with Equation 3 in the operation frequency range.

If T_M is eliminated between Equations 1 and 3, the following relationship exists, where $I_c = (I_{\phi} + n^2 I_M)$:

$$I_c \frac{d^2 \phi}{dt^2} + n^2 D_M \frac{d\phi}{dt} + nK a_2 \frac{d^2 \psi}{dt^2} + (H + nK a_1) \frac{d\psi}{dt} + nK a_0 \psi = n^2 I_M \frac{d^2 \chi}{dt^2} + n^2 D_M \frac{d\chi}{dt} + me \frac{d^2 z}{dt^2} \quad (4)$$

Solving Equation 4 with Equation 2 for ψ yields

$$I_c I_{\psi} \frac{d^2 \psi}{dt^2} + (I_{\psi} n^2 D_M + I_c D + H nK a_2) \frac{d\psi}{dt} + (n^2 D_M D + H(H + nK a_1) + H nK a_0) \psi = \left(n^2 I_M \frac{d^2 \chi}{dt^2} + n^2 D_M \frac{d\chi}{dt} + me \frac{d^2 z}{dt^2} \right) H \quad (5)$$

The left-hand members of this equation charac-

TABLE I—NOMENCLATURE

Symbol	EXPLANATION	Dimensions
ϕ, θ	Angles of gimbal frame referred to horizon	radians
ψ	Gyro angle around precession axis	radians
χ	Aircraft roll angle	radians
ξ	Aircraft pitch angle	radians
I_{ψ}	Moment of inertia of gyro around precession axis	gr-cm ²
I_{ϕ}	Moment of inertia of gyro and gimbal frame around ϕ -axis	gr-cm ²
I_M	Moment of inertia of torque motor armature	gr-cm ²
I_c	Moment of inertia of gyro, gimbal frame, and motor armature (in single-degree-of-freedom gyro)	gr-cm ²
I_o	Moment of inertia of gimbal frame and motor rotor (in two-degree-of-freedom gyro)	gr-cm ²
M	Mass of the platform	gr
e	Mass shift	cm
Z	Coordinate of platform system normal to e and the gimbal axis in question	none
H	Angular momentum of gyro	gr-cm ² /sec
D	Viscous damping coefficient of gyro precession axis	dyne-cm-sec
D_M	Viscous damping coefficient of torque motor (main part taken from steady-state torque-speed curve $\partial T/\partial(\text{rpm})$)	dyne-cm-sec
T_M	Torque applied by torque motor	dyne-cm
n	Gear ratio	none
a_0	Control coefficient of angle	none
a_1	Control coefficient of rate	sec
a_2	Control coefficient of rate of rate	sec ²
K	Torque motor coefficient (derived from $K_1 \times G(s) \times K_2 \times T_M$)	dyne-cm/radian

terize the undisturbed system; those on the right-hand side describe the disturbances. Applying Routh's criterion to this equation, if

$$(I\psi^2 D_M + I_e D + H n K a_2) \left(n^2 D_M \frac{D}{H} + H + n K a_1 \right) \geq I_e I \psi n K a_0$$

then Equation 5 represents a stable system.

Equation 5 will not be evaluated further. It should be noted, however, that the solution of the left-hand side is either three single complex roots or one single complex root and a conjugate pair of complex roots. As will be seen later, the single complex root is negative and the other two roots are, in most cases, a conjugate pair that produce a highly damped oscillation.

The equation describing the minor loop, in which $a_0, a_1, a_2 = 0$, is

$$I_e I \psi \frac{d^2 \psi}{dt^2} + (I \psi n^2 D_M + I_e D) \frac{d \psi}{dt} + (n^2 D_M D + H^2) \psi = 0 \quad (6)$$

The transfer function of ϕ as read from the block diagram for the complete system and for the disturbance

$$n^2 I_M \frac{d^2 \chi}{dt^2} + n^2 D_M \frac{d \chi}{dt}$$

$$\text{is } \frac{\Phi}{X}(s) = \frac{(n^2 I_M s^2 + n^2 D_M s)(I \psi s + D)}{\Delta_1} \quad (7)$$

where

$$\Delta_1 = I_e I \psi s^3 + (I \psi n^2 D_M + I_e D + H n K a_2) s^2 + [n^2 D_M D + H(H + n K a_1)] s + H n K$$

or, in the ω -domain

$$\frac{\Phi}{X}(j\omega) = \frac{-(n^2 I_M \omega^2 - j n^2 D_M \omega)(I \psi j \omega + D)}{\Delta_2} = \frac{A}{\Delta_2} \quad (8)$$

$$\text{Here } A = -(n^2 I_M \omega^2 - j n^2 D_M \omega)(I \psi j \omega + D)$$

$$\text{and } \Delta_2 = [H n K a_0 - (I \psi n^2 D_M + I_e D + H n K a_2) \omega^2] + j [n^2 D_M D + H(H + n K a_1) - I_e I \psi \omega^2] \omega$$

The transfer function of ϕ for the disturbance $me(d^2 z/dt^2)$ is

$$\frac{\Phi}{Z}(s) = \frac{m e s^2 (I \psi s + D)}{\Delta_1} \quad (9)$$

$$\text{or } \frac{\Phi}{Z}(j\omega) = \frac{m e^2 (D + j I \psi \omega)}{\Delta_2} \quad (10)$$

in the ω -domain in which Δ_1 and Δ_2 are the same polynomials as above.

The transfer function for ψ is

$$\frac{\Psi}{X}(s) = \frac{H(n^2 I_M s^2 + n^2 D_M s)}{\Delta_1}$$

$$\text{or } \frac{\Psi}{X}(j\omega) = \frac{-H(n^2 I_M \omega^2 - j n^2 D_M \omega)}{\Delta_2} = \frac{B}{\Delta_2} \quad (11)$$

$$\text{and } \frac{\Psi}{Z}(s) = H \frac{m e s^2}{\Delta_1}$$

$$\text{or } \frac{\Psi}{Z}(j\omega) = -H \frac{m e \omega^2}{\Delta_2} \quad (12)$$

Equation 8 above indicates that the platform deviates under a constant sinusoidal oscillation because of the damping D and the moment of inertia I_e of the gyro.

As shown in Equation 11, a precession will occur around the axis. The geared-up motor is responsible for the mass and friction coupling, and a direct-drive motor would eliminate the mass coupling and substantially reduce the friction. The effect of the mass coupling through $me(d^2 z/dt^2)$ can be studied by evaluating Equations 9 and 12. The structure of the gyro cluster and of the gimbals should be rigid to keep the mass shift within limits.

Gear trains are often used to keep the servomotor small and light. Motor and gearing are mounted on a frame immediately outside the gimbal or housing. Under flight conditions this frame can oscillate with respect to the gyro plate, and since the armature of the torque motor is coupled to this plate by gearing, the plate must accelerate and decelerate the armature accordingly. The rotor moment of inertia develops a reaction torque on the gyro plate, and the plate deviates slightly at the frequency of the airframe oscillations. In Figure 1, the

TABLE II — COMPARISON OF SERVO SYSTEMS

Item	Servo System for Three-Gyro Platform	Servo System for Two-Gyro Platform
System's equation	Third order	Second order
System's natural frequency	(For reference, the two systems oscillate equally)	(For reference, the two systems oscillate equally)
Adjustment of loop	Harder	Easier
Control signal pickoff	On gyro precession axis	On gyro gimbal axis
Gyro gain	H/D	1
Pickoff sensitivity to bearing play	Less	More
Preamplifier	Same	Same
Supply for pickoff frequency	Same	Same
Demodulator and remodulator	Same	Same
Phase correcting networks	Double lead	Single lead
Post-amplifier	Same	Same
Torque motor and gears	Same	Possibly stronger or higher
Moment of inertia of platform and gimbals	On the average slightly higher	In azimuth lower, but in roll or pitch not much difference
Static loop stiffness	Same	Same
Dynamic loop stiffness	Same	Same, as long as same motor and gear ratios are used

airframe oscillations are simulated by mounting the torque motor on an extra crank driven shaft.

The torque motor has viscous damping as a result of its falling torque-speed characteristic and friction in its bearings, gearing, and slip rings. These effects load up the gyro plate and constitute another cause of oscillatory deviations.

If the gyro plate and its gimbals are not accurately balanced a static mass shift can cause a disturbing torque around the gimbal axes if the platform is subjected to airframe vibrations perpendicular to the direction of the mass shift. Disturbing torques can also arise if the gimbal system is anisoclastic, in which case the mass shift is dynamic.

The single-degree-of-freedom gyro system has two special properties:

- a) Gain of the complete loop consists of two parts, namely, the gain of the electric portion (K_1, N_1, K_2) and the mechanical gain of the gyro. The latter is given by

$$\frac{\Psi}{\Phi} = \frac{H}{D + I\phi s} \text{ or } \frac{H}{D}$$

if we consider the static gain only.

- b) The pickoff moves through an angle that is H/D times larger than the platform angle ϕ . Consequently, the pickoff can be made less sensitive and the play in precession bearing is less critical than in the two-gyro platform where the control signal must be taken from the smaller angle ϕ of the gyro.

As will be seen later, the two-gyro servo system requires only a single lead network, whereas the three-gyro system depends on a double lead network which has a higher attenuation factor and requires a slightly higher gain in the amplifiers. But the gyro gain will not be fully compensated by this, and the advantage on the mechanical side is more important than a partial loss on the electrical side.

Servo system for two-gyro platforms

With reference to Figure 1B, the sum of all the torques around the ϕ axis is expressed as follows:

$$I_\phi \frac{d^2\phi}{dt^2} + n^2 I_M \left(\frac{d^2\phi}{dt^2} - \frac{d^2\chi}{dt^2} \right) + n^2 D_M \left(\frac{d\phi}{dt} - \frac{d\chi}{dt} \right) + T_M = me \frac{d^2z}{dt^2} \quad (13)$$

The torque motor equation has the form

$$T_M = nK \left(a_0 \phi + a_1 \frac{d\phi}{dt} + \dots \right) \quad (14)$$

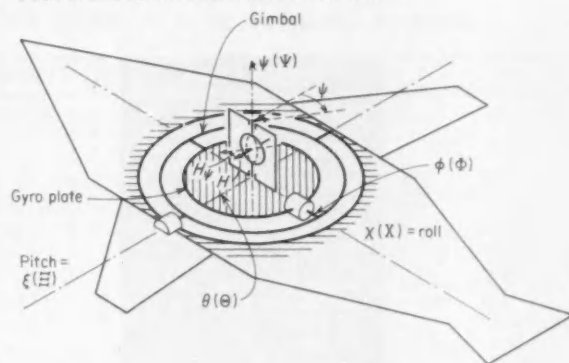
If T_M is eliminated between these equations we have

$$I_\sigma \frac{d^2\phi}{dt^2} + (n^2 D_M + nKa_1) \frac{d\phi}{dt} + nKa_0 \phi = n^2 I_M \frac{d^2\chi}{dt^2} + n^2 D_M \frac{d\chi}{dt} + me \frac{d^2z}{dt^2} \quad (15)$$

Routh's criterion for this case is that all the coefficients on the left-hand side have the same sign.

The transfer functions of the system for the disturbance $n^2 T_M s^2 + n^2 D_M s$ is

FIG. 2. Illustration of the rectification effect.



$$\frac{\Phi}{X}(s) = \frac{n^2 I_M s^2 + n^2 D_M s}{I_\sigma s^2 + (n^2 D_M + nKa_1)s + nKa_0} \quad (16)$$

and, in the ω -domain,

$$\frac{\Phi}{X}(j\omega) = \frac{-(n^2 I_M \omega^2 - jn^2 D_M \omega)}{(nKa_0 - I_\sigma \omega^2) + j(n^2 D_M + nKa_1)\omega} \quad (16a)$$

The transfer functions for $me(d^2z/dt^2)$ are, in the s -domain,

$$\frac{\Phi}{Z}(s) = \frac{mes^2}{I_\sigma s^2 + (n^2 D_M + nKa_1)s + nKa_0} \quad (17)$$

and in the ω -domain

$$\frac{\Phi}{Z}(j\omega) = \frac{-me\omega^2}{(nKa_0 - I_\sigma \omega^2) + j(n^2 D_M + nKa_1)\omega} \quad (18)$$

Equation 15 is the system equation and is of the second order, i.e., one order lower than the single-degree-of-freedom system. It has two single complex roots, or one conjugate pair of complex roots. The latter solution represents a normally highly-damped oscillation. This simplifies the mathematical treatment of the platform as well as that of the shaping networks. However, the gyro gain of the system is only unity, and this makes it necessary to increase gain of the amplifiers and, possibly, the gear ratio and motor size. The latter case might be dictated by the noise level of the pickoff.

Comparison of the two servo systems

Table II compares the behavior and hardware requirements of both system types. It shows that for a one-axis platform, the hardware for the two systems is about the same. In the two-degree-of-freedom gyro system the simpler lead network and its adjustment is balanced against the difficulties with the pickoff on the gimbal axis (bearing play, gimbal stiffness producing zero shift and noise) and the absence of gyro gain.

GYRO OSCILLATION ERRORS

The above discussion indicates that the plate on which the gyros are mounted can oscillate around three axes. Although the amplitudes of these oscillations are very small, they do disturb the gyros and cause drift. This drift is a systematical error and cannot be avoided, but it can be minimized by proper design. Contributing factors are the gyroscopic effect, the mass and viscous damping of the

TABLE III — COMPARISON OF PLATFORM TYPES

	Two-Gyro Platform	Three-Gyro Platform
Float	Must be balanced precisely around two axes (center of gravity, center of flotation with center of support). Distribution of heat flow symmetrical.	Less difficult, precision balancing only around one axis.
Extra gimbal	Must be; small to avoid paddle effects; balanced and floated to avoid disturbing torques and friction; rigid to keep the float in position for the benefit of the pickoffs and torquers.	Does not exist.
Flex leads	Higher in number; two torquers, two pickoffs, and one gyro motor; must be flexible in two directions; are attached to a lever arm longer than the radius of the ball-shaped float (residual torques in zero position).	Fewer in number; one torquer, one pickoff, and one gyro motor; flexible in one direction, attached close to the center line of the precession axis (risk of residual torque much smaller).
Position pickoff	High stiffness of platform loop requires a small signal range. High pickoff sensitivity and bearing play can cause uncertainties in the control signal.	Due to gyro gain the signal range is H/D times greater and the pickoff less sensitive to play in bearings.
Torquers	Built for motions in two directions (larger air gap).	Built for motion in one direction.
Lead networks	One single network only.	Double network required.
Number of gyros	Two only	Three required.
Power Consumption		Additional power for the third gyro.
Weight		Additional weight for third gyro.
Size of platforms		Probably equal, because three gyros give a better density factor for packaging.

fluid, the moment of inertia of the platform members, and geometry of the gyro arrangement.

In the single-degree-of-freedom gyro, there is a nonlinear coupling and an interaxis cross coupling, whereas in the two-degree-of-freedom gyro there is a cross coupling and a nonlinear mass coupling.

The nonlinear coupling of the single-degree-of-freedom gyro is caused by the fact that this gyro must precess to produce a control signal. The platform with this type of gyro also has an interaxis cross coupling caused mainly by the moments of inertia of the gyros around their precession axes. In a good design with low values of I_ψ/H and D/H , and a nearly nongyroscopic arrangement, this coupling can be neglected.

In the two-degree-of-freedom gyro the cross coupling is caused by the viscous friction of the fluid when there is relative motion between the gimbals and gyro sphere. A mass coupling also arises when the inner gimbal moves and pushes the fluid out of its way. This is a nonlinear effect depending on the size and shape of the surrounding gimbal and on the frequency and amplitudes of the azimuth and inner gimbal motions.

With proper design, all errors mentioned for both platforms can be kept within acceptable limits.

Nonlinear coupling, or rectification effect, is illustrated in Figure 2. Derivation of the governing equations follows:

Assume that, under the effect of a torque around the ϕ -axis, the gyro has precessed through an angle ψ . Now the angular momentum vector has a component along the input axis of the amount $H\psi$. If, at the same time, the platform rotates around the θ axis, a torque equal to $H\psi(d\theta/dt)$ develops around the ψ -axis. As a result, the platform starts to drift around the input axis ϕ , and

$$H\psi \frac{d\theta}{dt} = H \frac{d\phi}{dt}$$

$$\text{or} \quad \frac{d\phi}{dt} = \psi \frac{d\theta}{dt} \quad (19)$$

This drift effect can also be caused by oscillations of the gyro plate around the ϕ and θ axes. The two oscillations must be equal in frequency but different in phase, so that one velocity component of one oscillation is in phase with the position component of the other oscillation which will normally occur. Since both oscillations change their signs periodically, the drift occurs in one direction only. The mean value of this drift is

$$\overline{d\phi/dt} = \frac{1}{2} \psi \omega \Theta$$

expressed in angles of the gyro plate.

To introduce the aircraft motions, the plate angles ψ and θ are replaced by the aircraft angles χ and Ξ with the help of the transfer functions

$$\frac{\psi}{\chi}(j\omega) = \frac{B}{\Delta_2} \text{ and } \frac{\theta}{\Xi}(j\omega) = \frac{A}{\Delta_2} \quad (11) \text{ and } (8)$$

If it is assumed that the two servo loops behave in the same manner, i.e., that they have the identical constant Δ_2 , these equations can be written in final form as follows:

$$\overline{d\phi/dt} = \frac{\omega A}{2\Delta} \Xi - \frac{B}{\Delta} \chi = \frac{\omega AB}{2\Delta^2} \chi \Xi \quad (20)$$

INSTRUMENTATION

On the theoretical basis, a comparison of the two platforms can be objective because the results can be derived from mathematical considerations. With regard to instrumentation, however, a comparison is partly objective and partly subjective if complete information on the hardware, fabrication time, etc. is not available. Consequently, the comparison of platform types presented in Table III is for the most part of an objective nature.

Designing Sampled-Data Systems

THE GIST: Whether for open-loop information or closed-loop control systems, sampled-data procedures offer efficient means of handling signals.

Some advantages are:

- sampled-data techniques apply to both analog and digital signals
- sampled signals, particularly after being converted to digital form, can be stored for later transmission and signal reconstruction
- the time-discrete nature of the sampled signal leads to the possibility of sharing one transmission link with other similar signals.

The fidelity with which a sampled-data system restores the original signal to continuous form depends on five interdependent factors:

- the measured variable and its transducer
- the input filter for attenuating unwanted frequencies in the signal
- the sampling time aperture
- the sampling rate
- the data recovery circuit and filter for reconstructing the original data samples

B. M. GORDON and W. H. SEAVER
Epsco, Inc.

Designing a sampled-data system requires, first of all, a thorough knowledge of the frequency spectrum of the measured signal. A typical continuous time-varying input signal, Figure 1, contains two major components, the desired measurement and superimposed noise. The desired signal generally has a frequency spectrum extending to some maximum frequency that is limited by the dynamic response of the transducer or of the measured source. Superimposed noise includes spurious signals and broadband noise. Spurious signals may be introduced by ac power sources, ground-loop currents, and transducer vibration. While spurious signals may have almost any frequency spectrum, generally they are characterized by one or two predominant frequencies and by an average value. Broadband noise by definition has a spectrum extending to frequencies greater than the sampling rate and may arise from amplification of low-level transducer signals.

Spurious signals and broadband noise constitute

unwanted information that contributes dynamic error to the measurement. Some of this dynamic error may be reduced by using an input filter in the sampled-data system, see box. The input filter should have a flat frequency characteristic out to the highest frequency-of-interest and then should cut off smoothly and with maximally linear phase to attenuate all higher frequencies. For example, such a filter would attenuate the high-frequency peak—due to a spurious signal—in Figure 1D.

Most practical sampled data systems require input filters ranging from a simple one-pole passive RC network to a five-pole active (amplifier) filter. Often the transducer may act as the low-pass filter. Since any practical input filter does not have an absolutely flat frequency response out to the cutoff frequency, the filter itself introduces an attenuation error which must be taken into account. For instance, a two-pole critically damped filter introduces a 6-db attenuation (a 50-percent input amplitude error) at the cutoff

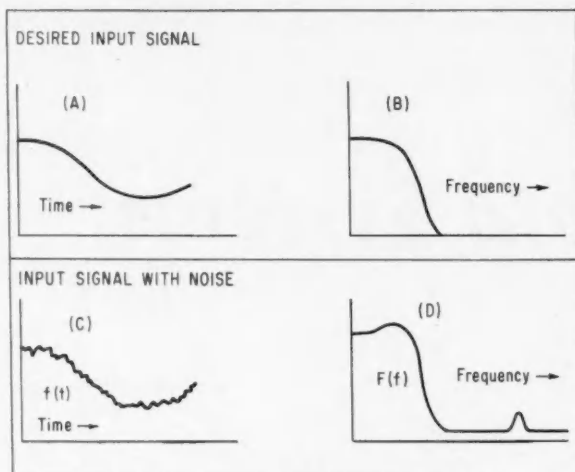


FIG. 1. System's input signal contains unwanted high frequencies that may have to be filtered.

frequency. When the exact characteristics of the input filter are known, it is theoretically possible to compensate for this error by using an inverse characteristic in the data recovery circuits, but this is not often practical.

The question may then be asked: Why not eliminate the input filter and do all necessary noise filtering after the sampled signal has been reconstructed? This is not usually feasible. When frequencies greater than the maximum frequency-of-interest, whether from desired data or noise, are present in the signal then the very nature of the sampling process introduces dynamic errors. No amount of

post-reconstruction filtering or data interpolation can reduce these inherent errors once they are introduced at the sampler.

THE SAMPLING PROCESS

A continuous analog signal $f(t)$, Figure 1C, varies with time and has a frequency spectrum $F(f)$, Figure 1D. The analog signal is sampled periodically by a pulse train $p(t)$ having a period T and a pulse duration t_0 , Figure 2A. The resulting frequency spectrum $P(f)$ is shown in Figure 2B. The frequency spectrum $P(f)$ is not continuous but is rather a spectrum of discrete frequencies at zero and n/T cps, where n is a series of integers. The line spectrum is contained in an envelope defined by

$$\left[\frac{2t_0}{T} \times \frac{\sin \pi t_0 f}{\pi t_0 f} \right]$$

which goes to zero at k/t_0 cps, where k takes positive and negative integer values.

When the analog signal $f(t)$ is sampled by the pulse train $p(t)$ the process forms a new time function $f^*(t) = f(t)p(t)$, Figure 3A. The resulting frequency spectrum $F^*(f)$, Figure 3B, contains the sum and differences of all frequencies present in $F(f)$ and $P(f)$. Note that the data frequency spectrum $F^*(f)$, Figure 3B, folds about each line spectra of $P(f)$ and that the amplitude is attenuated.

In the sampling process the sampling time aperture t_0 , the sampling rate $1/T$, and the data recovery circuit and filter may give rise to dynamic error, and these factors as well as the input filter must be given due consideration when designing a system.

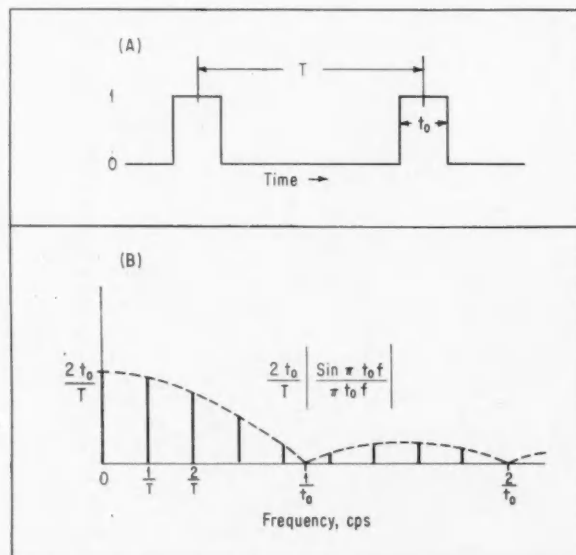


FIG. 2. Sampling waveform $p(t)$ and corresponding frequency spectrum $P(f)$.

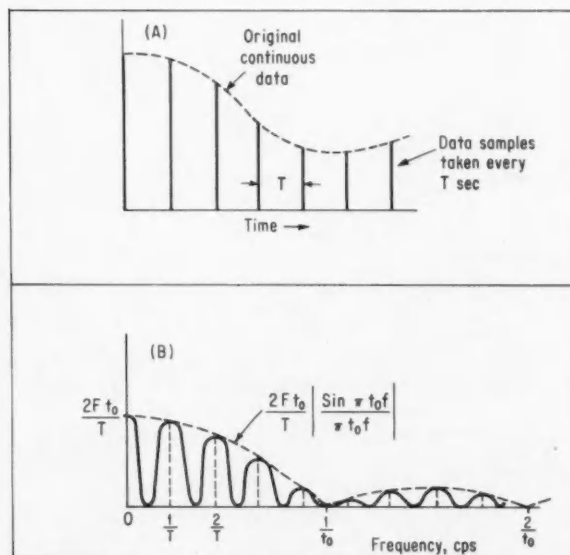
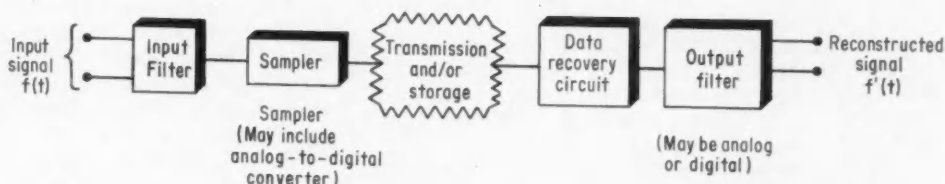


FIG. 3. Sampled-data pulses $f^*(t)$ and corresponding sampled-data frequency spectrum $F^*(f)$.

BASICS OF A SAMPLED-DATA SYSTEM



A low-pass input filter removes noise and unwanted high frequencies from the input signal coming from the transducer. The sampler periodically measures the filtered input signal and produces a series of data samples. After transmission, which may include storage at either end of the transmission link, the data samples reach

a data recovery circuit that reconstructs the original information. The display device or an output filter removes high frequencies introduced by the sampled-data pulse train to produce a continuous signal which is a fairly faithful reproduction of the original information. Good signal restoration depends on five practical design factors.

Sampling time aperture

The sampling pulse requires a finite time, the sample aperture time t_0 , to take a data sample. The sample aperture is, therefore, equivalent to an uncertainty in the exact time the data is sampled. This time uncertainty introduces an error in the sampled data. Figure 3B shows that the amplitude at any frequency of $F^*(f)$, including the one at zero frequency, is attenuated by the factor:

$$\left[\frac{2Ft_0}{T} \times \frac{\sin \pi t_0 f}{\pi t_0 f} \right]$$

where F is the input signal amplitude. It is this amplitude attenuation that introduces the errors attributed to the finite sampling aperture. The percentage error due to sample aperture time can be calculated from

$$100 \left\{ 1 - \left[\frac{\sin \pi t_0 f_d}{\pi t_0 f_d} \right] \right\}$$

where f_d is the information frequency of interest and $1/t_0$ is the frequency at which

$$\left[\frac{\sin \pi t_0 f}{\pi t_0 f} \right] = 0$$

Figure 4, a useful design chart, plots the percentage error due to sampling aperture as a function of $f_d t_0$ and shows that the error becomes smaller as t_0 decreases. The sampling rate $1/T$ does not affect this error. (Figure 4 may also be used, by replacing t_0 with T , to evaluate errors introduced by a zero-order data recovery circuit; this is discussed later.)

When the sampled signal is converted to a digital number, as by an analog-to-digital converter using successive approximation techniques, the maximum time uncertainty is related to the time required for

a complete digital conversion. If t_0 is set equal to the maximum conversion time, then a maximum limit is set on the resulting time uncertainty. Actually, depending on the magnitude and slope of the varying input signal, the average value of t_0 is less than half the digital conversion time and the average error is a good deal less.

If the dynamic error due to the finite aperture is greater than system specification will allow, a sample-and-hold circuit (often called a zero-order hold or clamp) may be necessary. This circuit samples the input at precise intervals and holds the input amplitude constant for the duration of the sampling time even though the measured signal itself is varying. A practical sample-and-hold circuit prior to the sampler, if it is needed, reduces the time uncertainty t_0 to less than a microsec, the circuit's effective disconnect time. When is a sample-and-hold circuit required for accurate sampling and digital conversion of input data with a specified frequency characteristic?

EXAMPLE: A system samples data having a maximum information frequency of 200 cps and encodes (converts) the resultant sample to a digital code with a permitted error of 0.5 percent. The encoder takes 5 microsec per bit, or 50 microsec to make a complete conversion.

Therefore:

$$t_0 f_d = 50 \times 10^{-6} \times 200 = 0.01$$

and from Figure 4 the dynamic error, with no sample-and-hold, is 0.015 percent at 200 cps. Since one digital increment introduces a resolution error of $(1/2^{10}) = (1/1,024) = 0.1$ percent, the sample-and-hold circuit would not be needed for this case.

EXAMPLE: The same converter as above samples

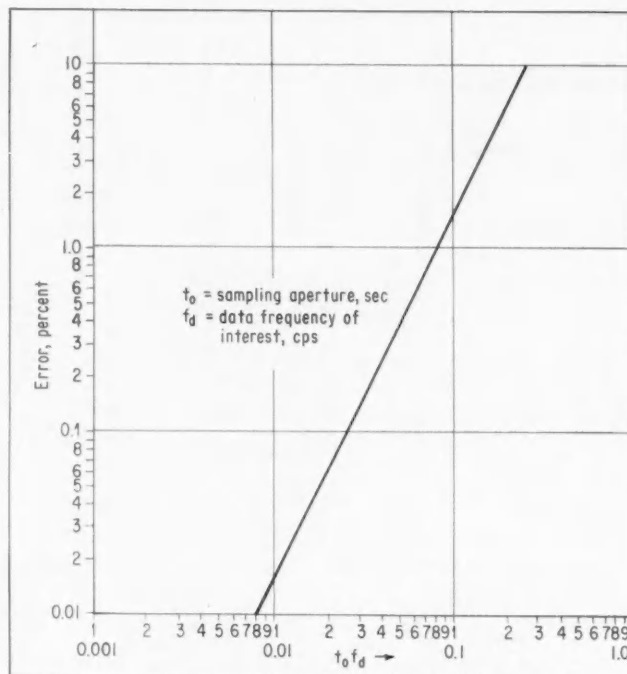


FIG. 4. Magnitude of error, in train of sampled-data pulses, caused by a finite sampling aperture t_o .

a signal with maximum information content up to 2,000 cps. Therefore, $t_o f_d = 0.1$ and the maximum error from Figure 4 is 1.6 percent. Since this exceeds the permitted error of 0.5 percent, a sample-and-hold circuit may be required.

Many data systems, however, do not require the same accuracy at high frequencies that they do at steady state. The theoretical increase in dynamic accuracy afforded by a sample-and-hold circuit may actually be outweighed by the amplifier errors and by the slight decrease in reliability caused by the additional components. A good engineering compromise, with full knowledge of the system data accuracy requirements, is needed.

One-shot analysis is wrong

Dynamic error caused by a finite sampling aperture must always be evaluated on the basis of the maximum frequencies present in the input, as done above, and not on the one-shot basis which stipulates that the aperture must be small enough to permit the input data to change no more than one least-significant bit during the time of uncertainty. A one-shot analysis can lead to some wrong and perhaps expensive conclusions, particularly when using it to determine the need for a sample-and-hold circuit.

An example of the erroneous use of a one-shot analysis is as follows: A sine wave signal is assumed

and its maximum slope—the slope at zero crossing—is calculated:

$$\text{max slope} = B\pi f_d \text{ bits per sec}$$

where B is binary value of the full-scale amplitude of the sine wave and f_d is the sine wave frequency. If the input data with maximum slope conditions cannot change more than the equivalent of one least-significant output bit during t_o , then

$$\text{max slope} < 1/t_o$$

Equating the two factors at the right of the above expressions,

$$f_d < 1/(B\pi t_o) \text{ cps}$$

Suppose an 11-bit word analog-to-digital converter takes 2 microsec per bit conversion, or 22 microsec for total word conversion. The full-scale binary value B is 2^{11} or 2,048. Therefore,

$$f_d < 1/(2,048 \times 3.14 \times 22 \times 10^{-6}) < 7 \text{ cps}$$

This low maximum frequency is a faulty answer because it is based on the very special case where only one sample is taken near the zero crossing of a maximum amplitude sine wave. Actually data is sampled continuously (even when the input signal is a transient) and therefore the digital values obtained from the sequence of conversions are correct at some time within their respective

t_o intervals. That is, any error must be considered one of time and not of amplitude. When the data samples are restored to a continuous signal in a data reconstruction device, each sample is weighted by nearby samples. The final error in the reconstructed signal is therefore much less than inferred from the one-shot analysis.

For the 11-bit a-d converter used in the one-shot analysis case, the resolution error is $1/2,048$, or about 0.05 percent. Allowing the same maximum value for sampling aperture error and performing a continuous-sampling analysis, then from Figure 4 $t_o f_d = 0.02$ and therefore $f_d \approx 900$ cps. Thus, whereas the one-shot analysis indicated only 7 cps, a frequency that mistakenly shows the need for a sample-and-hold circuit to reduce t_o , the continuous analysis shows that input signals containing frequencies up to 900 cps can actually be accommodated quite well without a sample-and-hold device. Simplicity, reliability, and operation are enhanced.

Sampling rate

Because sampled-data systems use data taken at discrete intervals and discard the data between samples, intolerable errors may be introduced in the sampled-data pulse train. These errors, caused by frequency folding of the original data frequencies about the sampling frequency, as shown in Figure

3B, can be reduced first by filtering higher frequencies (including noise of unwanted signal) out of the input signal and by the filtered input sampling at an adequately high rate.

Figure 5 assumes an input signal having a frequency spectrum flat out to the sampling rate $1/T$ cps which is modified at high frequencies by two typical filters, a one-pole filter falling off at 6 db per octave and a five-pole filter falling off at 30 db per octave. For simplicity, only the asymptotes of the filters—both of which have break points at f_m , the maximum information frequency—are shown. At the right of Figure 5 are sampled-data spectra folded about the sampling rates $1/T = 5f_m$ and $1/T = 10f_m$. The dynamic error due to frequency folding is that portion of the folded data that extends back to frequencies below f_m , and is in addition to any error the filter's attenuation may cause at any frequency.

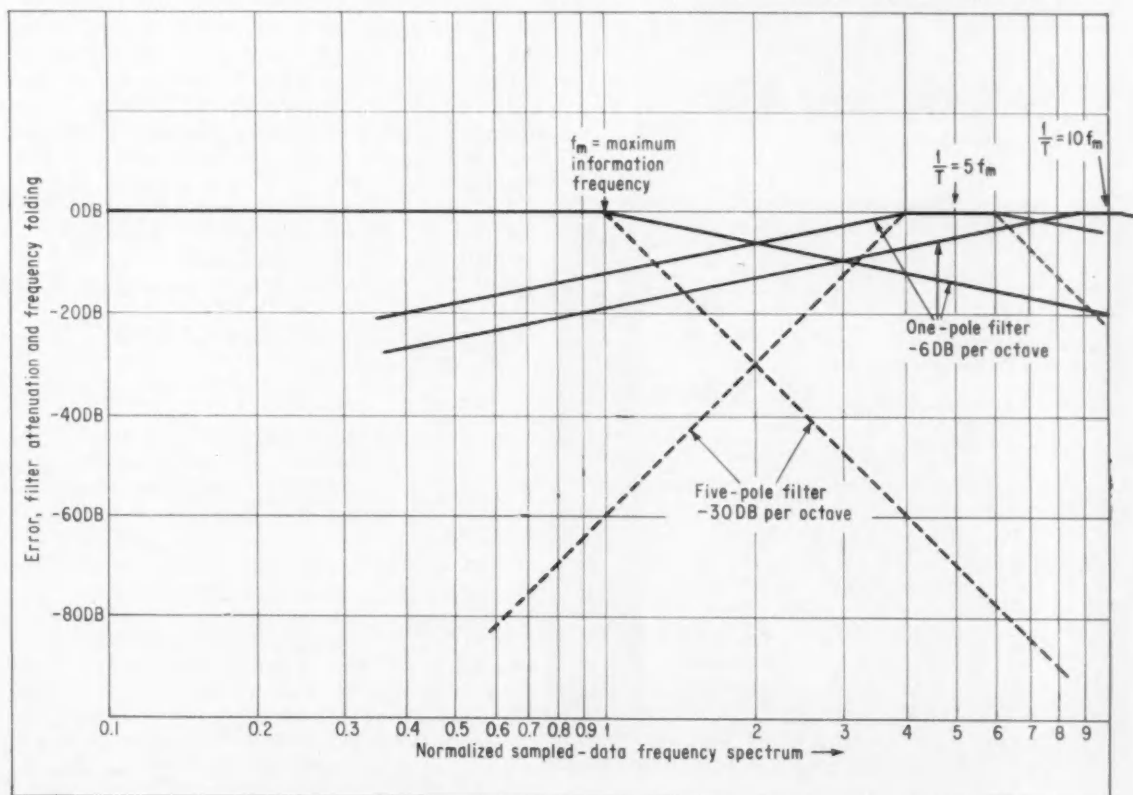
To achieve required accuracy at a given data frequency, it is important to make a sound engineering compromise between input filter design and the sampling rate:

EXAMPLE: Information to a sampled-data sys-

tem has a frequency spectrum flat out to the sampling rate. A one-pole RC network with a break frequency of f_m filters the input data before sampling. The attenuation characteristic of such a filter is shown in Figure 5. Here, the filter reduces the input signal 3 db at f_m , an error of about 29 percent. This error can be compensated somewhat by the output filter. However, from Figure 5, the folded-data spectrum is down 12 db at f_m , an error of 25 percent at that frequency, and is down 20 db at $0.4 f_m$, an error of only 10 percent at that frequency. This error cannot be corrected by recovery or filter circuits. Note how using the same input signal and filter but increasing the sampling rate to $1/T = 10 f_m$ reduces the dynamic error.

EXAMPLE: Information to a data sampler is filtered to give a frequency spectrum flat to f_m and then to attenuate at minus 30 db per octave above f_m . The sampling rate is $5 f_m$. As shown in Figure 5 for these conditions, the folded data spectrum is down 60 db at f_m , an error of 0.1 percent at that frequency. Here, the five-pole filter does a much better job of reducing frequency

FIG. 5. Error caused by frequency folding can be alleviated by using a filter with sharp cutoff characteristics and increasing sampling rate.



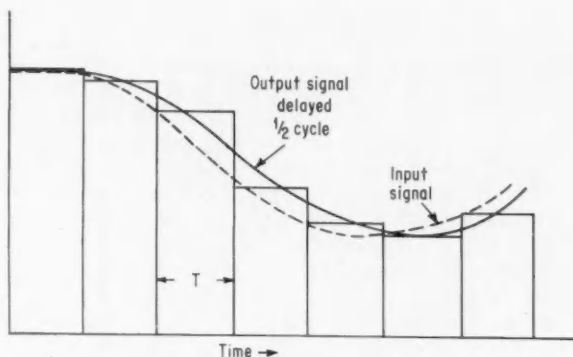


FIG. 6. Zero-order data hold output.

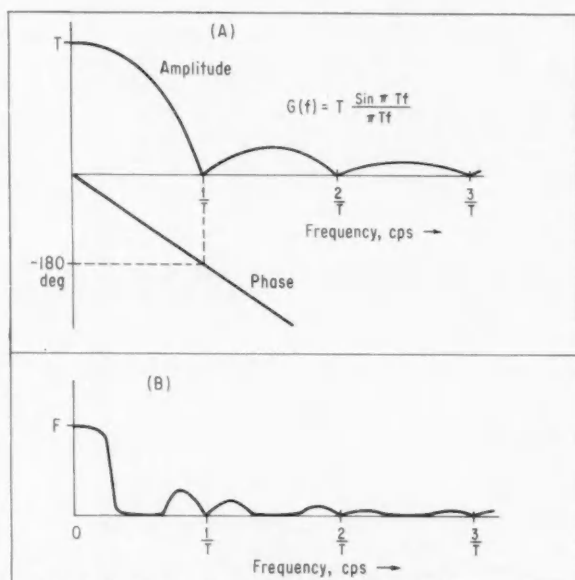


FIG. 7. When data samples $F^*(t)$ pass through a zero-order data hold, A, the resulting frequency spectrum contains unwanted high frequencies, B.

folding error than does the one-pole network of the preceding example.

Thus, to achieve required accuracy at a given data frequency one must make a compromise between using a filter with sharper cutoff characteristics and increasing the sampling rate.

The two preceding examples also show the need for a high speed analog-to-digital converter to encode data for many data systems. For instance, when information up to 2,000 cps must be accurately transmitted and the sampling rate is five times this, then the converter rate must be at least 10 kc. When the channel is time-division multi-

plexed with other channels, as is often done, the conversion rate may be about 20 or 30 kc. Commercial analog-to-digital converters have been available for many years which can run at rates up to 50 kc, and recent equipment employing advanced solid-state components and circuits make possible data conversion rates up to several megacycles.

Recovering original data from samples

A data-hold, or data-reconstruction, circuit recovers the original signal from the sampled data. Errors introduced by the data-hold circuit depend on the method used for filling in data gaps between samples. The most common data reconstruction circuit is the zero-order data hold, or boxcar desampler, that extrapolates the time function between pulses by holding the data constant at the value of the last data pulse, Figure 6.

The desampling of sample pulses with a zero-order data hold is equivalent to passing the sampled-data pulses through a low-pass filter with a transfer function:

$$G(f) = T \frac{\sin \pi T f}{\pi T f} \angle -\pi T f$$

The amplitude and phase characteristics of $G(f)$ are shown in Figure 7A. As a result of going through the boxcar filter, the data samples now exhibit a frequency spectrum like that shown in Figure 7B. Here, besides introducing a calculable error in the form of unwanted attenuation of frequencies within the desired-data spectrum, the desampler also passes some high-frequency components present in the sampler-data pulses. These unwanted high frequencies appear in the output and may require filtering for some critical system applications.

Once the extraneous frequencies are filtered out, the dynamic error introduced by desampling may be read from the curves of Figure 4 when t_0 is replaced by T . (Note that $G(f)$ is similar in form to the function describing the envelope of the spectra amplitudes on which Figure 4 is based.)

The phase of $G(f)$ drops off linearly with frequency, indicative of a pure time delay. Since the phase angle is minus 180 deg at $1/T$ cps, the time delay is one-half the sampling period T . This time delay is not important for most data logging systems, but it may become significant when the sampled-data system employing a zero-order hold circuit forms part of a closed-loop control system.

As examples of error magnitude when using a boxcar desampler, Figure 4 shows that at $1/T = 5 f_m$ (or $t_0 f_d = 0.2$) the error is 6.4 percent; and at $1/T = 10 f_m$ the error is 1.6 percent. When such accuracy is not good enough better results can be obtained by employing data holds of higher order where prediction between data samples is used. A digital computer, for instance, may be programmed as a first or second-order hold to serve as a data reconstruction filter to give greater dynamic accuracy.

Curve Checks

Pot Loading Error

JULIUS DAMAST, Computer Instruments Corp.

The resistance selected for a precision potentiometer is usually a compromise between a high value to reduce current drain and a low value that will limit non-linearity due to electrical loading. In determining an acceptable level of resistance tolerance, the engineer must make allowance for the effects of changes in terminal resistance (caused principally by wear, temperature, humidity, voltage, and aging) after the potentiometer is installed in his system.

Here is a simple way to find the maximum linearity error for given values of pot and load resistance, and to evaluate the effect of load resistance variations.

Derivation

The general circuit in which precision potentiometers operate is shown in Figure 1. R_L , the electrical load in the wiper circuit, acts as a shunt, and its effect on the potentiometer output voltage can be analyzed as follows:

When R_L is infinite, no current is drawn through the wiper, and $E_o/E_{in} = S$. If R_L is less than infinite, let $E_o/E_{in} = M$ and $P = R/R_L$. By using Thevenin's theorem it can be shown that

$$M = \frac{SR_L}{(1-S)SR + R_L}$$

$$= \frac{1}{(1-S)P + (1/S)}$$

If this equation is expanded and Δ is defined as $(S - M)$, the change in E_o due to loading, then

$$\Delta = MS(1-S)P$$

$$= (S - \Delta)S(1-S)P$$

$$\approx S^2(1-S)P$$

since Δ is small compared to S . Taking the first derivative and equating it to zero to find the position S for maximum voltage change,

$$\frac{d\Delta}{dS} = (2S - 3S^2)P = 0$$

and

$$S = 2/3$$

Thus the maximum error in E_o due to load ratio P is $(4/27)P$. Figure 2 is a plot of this error.

SOME EXAMPLES

The use of Figure 2 to find the change in potentiometer output linearity produced by a change in terminal resistance is best illustrated by example:

1. When a 1-megohm load is connected between one fixed terminal and the wiper of a 10,000-ohm potentiometer ($R/R_L = 0.01$), the linearity error, from Figure 2, is 0.15 percent. A 50-percent change in terminal resistance, corresponding to a new load ratio of 0.015, shows an error of 0.22 percent. Thus

a 50-percent change in terminal resistance at this load ratio will produce a 0.07-percent ($0.22 - 0.15$) change in linearity.

2. When the load is connected between the potentiometer centertap and the wiper, divide R/R_L by two, and also divide the error read on the curve for this halved load ratio by two. If the 1-megohm load of the above example is connected to the centertap, $(R/R_L)/2 = 0.005$, and the linearity error is 0.036 percent. A 50-percent change in terminal resistance, $(R/R_L)/2 = 0.0075$, gives a linearity error of 0.054 percent. Thus a 50-percent change of terminal resistance in this circuit produces a linearity change of only 0.018 percent.

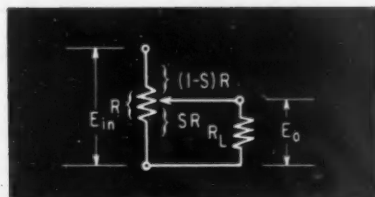


FIG. 1. General potentiometer circuit.

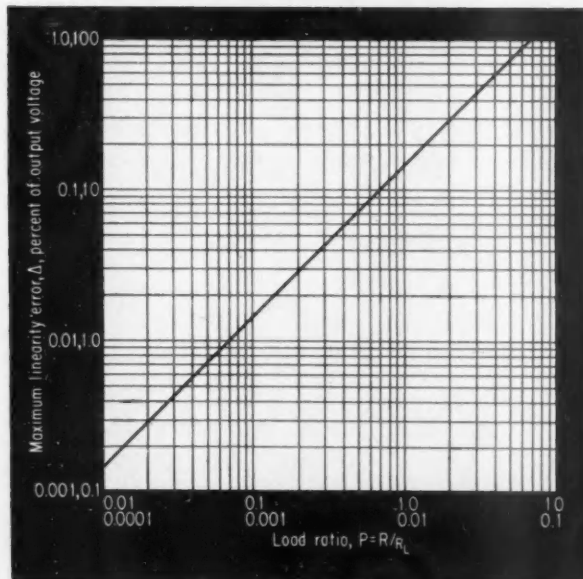
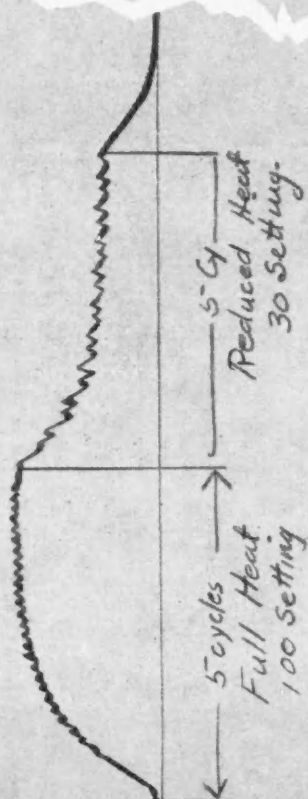
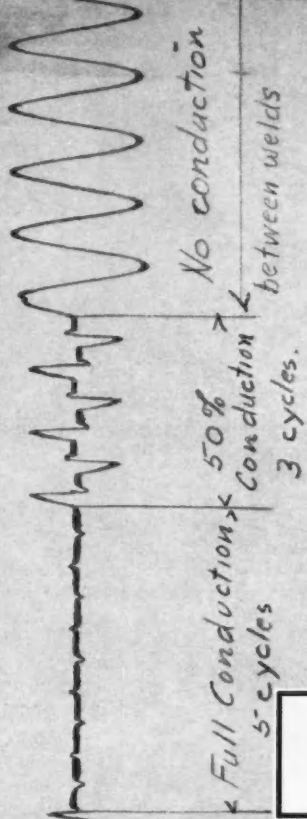


FIG. 2. A plot of linearity error due to loading.



Oscillogram of Welding Current Pattern D.C.
 Taken from shunt
 in lower arm of welder.

Shows gradual build-up
 and decline of welding current.
 Essential in making
 good spot welds



Oscillogram taken
 across ignition tubes.

this is a record



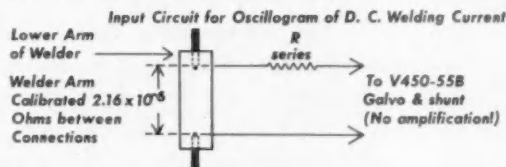
These welder phase-shift heat-control patterns were directly recorded with a Honeywell 906 Visicorder at Bristol Aircraft (Western) Limited in Winnipeg.

Since the welding heat generated is proportional to the square of the current value, phase shift must be accurately controlled in order to determine the heat value. If the phase shift dial is not accurately calibrated, the result is too much or too little heat, and a poor weld.

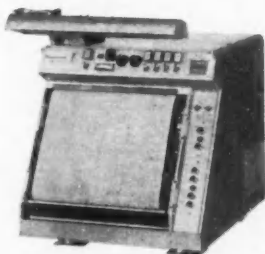
In this application, the Visicorder is an essential guide to accurate calibration, since ink-type re-

orders do not cover the sensitivities and frequencies needed and an oscilloscope would present a continually changing pattern since most recording periods are less than 10 cycles. The directly-recorded Visicorder patterns allow a convenient study of the exact time when the current wave form was being cut off.

Here is the circuit used in this test.

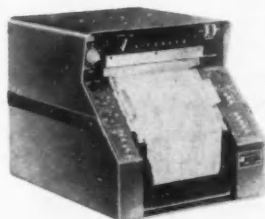


of phase shift



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Dynamics of pH Electrodes

A. L. GIUSTI, JR. and J. O. HOUGEN
Monsanto Chemical Co.

THE GIST: The pH electrode for determining hydrogen ion concentration is a primary measuring element and like other primary elements its dynamic response characteristics can play a significant role in control loop accuracy and stability. Unlike most other transducers, however, the pH electrode shows strong nonlinear dynamic characteristics. At least one of the two time constants describing the performance of the glass electrode varies during normal operation.

Just how seriously flow conditions, direction of pH change, and pH level affect time constant magnitudes is shown here by transient response curves taken from tests conducted on three different pH flow cells. The results verify—for the most part—an analytically derived two time constant transfer function characterization of the pH measuring electrode.

Such discerning information is meaningful, for recognizing both qualitatively and quantitatively that dynamic nonlinearity exists can lead to the design of improved closed-loop pH control systems.

The pH electrode for measuring hydrogen ion concentration in aqueous solutions exhibits a strong nonlinear dynamic response, a factor that must be given serious consideration when designing fast, stable pH control loops. For instance, in a given pH electrode installation it will not be unusual for time constants to change by a factor of two. Such a nonlinear response with time is in addition to the steady-state nonlinear (logarithmic) relationship between ion concentration and pH reading.

In a continuous flow cell, Figure 1, the pH electrode's response can be generally represented by

two time constants, one arising from the rate of diffusion of ions into and out of the glass electrode surface, the other from solution mixing within the flow cell. The cell's performance function, or transfer function, can then be written as:

$$[PF] = \frac{1}{(1 + \tau_1 s)(1 + \tau_2 s)}$$

where τ_1 is the mixing time constant
 τ_2 is the diffusion time constant

The diffusion time constant is primarily a function of the dynamic response of the glass measuring electrode itself. The mixing time constant is a function of the continuous flow cell in which the glass electrode measures the pH of the solution.

When the cell configuration and solution flow conditions provide minimum internal cell volume and high sample velocity, the mixing time constant may become negligible for all practical purposes. If not negligible, the mixing time constant will at least remain relatively constant in value for a particular installation. The diffusion time constant, however, is considerably nonlinear even for a given cell configuration and set of flow conditions. This time constant's value depends on the pH level and the direction of hydrogen ion movement—which will change because of process operating requirements and disturbances—and on film (boundary layer) dimensions and diffusion coefficient—which will remain relatively constant for a particular installation.

The analytical derivation of pH glass electrode dynamics and a description of the procedure and equipment for conducting experimental transient responses follow next. Such information aids in interpreting the actual sets of test results establishing dynamic nonlinearity which are plotted on pages 138 and 139.

Mixing time constant

Flow cells used for continuous pH measurement, Figure 1, contribute a mixing time lag in the electrode response. The mixing performance function is derived from a material balance:

$$V \frac{dc_o}{dt} = F_o (c_i - c_o)$$

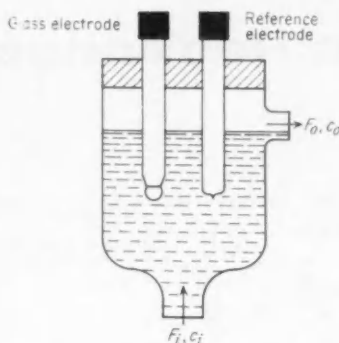


FIG. 1. Continuous flow cell for sampling.

where V is the cell's volume
 $F_i = F_o$ is the flow rate
 c_i is inlet hydrogen ion concentration
 c_o is outlet hydrogen ion concentration

Transforming and rearranging yields a performance function for mixing:

$$[PF]_{\text{mixing}} = \frac{C_o}{C_i}(s) = \frac{1}{(1 + \tau_1 s)}$$

where $\tau_1 = V/F_o$, and C_o and C_i are functions of the complex variable, s .

Diffusion time constant

The active area of the glass electrode is an extended three dimensional network of silicon atoms or ions surrounded by oxygen tetrahedrons. The holes, so to speak, are occupied by alkali metal cations such as sodium ions. When the surrounding hydrogen ion concentration decreases, ions migrate from the glass surface into solution unaffected by the sodium ions until a new equilibrium position is reached. However, when the hydrogen ion concentration increases, the ions now migrate into the glass but the attainment of a new equilibrium is retarded by movement of sodium ions in the glass. The electrode potential, determined by the instantaneous concentration of hydrogen ions on and within the glass, changes faster in one migration direction than the other. This movement of ions introduces a nonlinearity in τ_2 .

A very probable rate controlling mechanism determining pH electrode response is the diffusion of hydrogen ions through the boundary layer on the surface of the electrode, Figure 2. If it is assumed that resistance to diffusion is confined entirely to the boundary layer of uniform properties and that upon traversing the layer the hydrogen ions become immediately effective in altering the electrode potential, then as in heat transfer,

$$\frac{dN}{dt} = -KA \frac{dc}{dx}$$

where N is the effective number of hydrogen ions diffusing, A is the diffusion area, x is the boundary layer thickness, c is the hydrogen ion concentration as indicated by the pH instrument, and K is the effective diffusion coefficient.

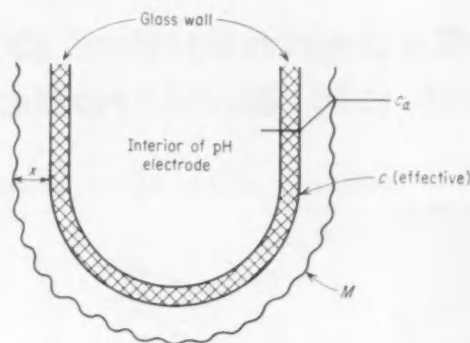


FIG. 2. Boundary film around glass electrode.

Assuming a linear gradient in the film,

$$\frac{dc}{dx} = \frac{c - c_a}{x}$$

where c_a is the hydrogen ion concentration in the flowing solution surrounding the electrode. Finally, the change in hydrogen ion inventory in the electrode, beyond the boundary layer, is

$$\frac{dN}{dt} = \bar{C} \frac{dc}{dt}$$

where $\bar{C} = dN/dc$ = capacitance of electrode system for hydrogen ions. Combining yields:

$$\frac{\bar{C}}{KA} \frac{dc}{dt} + c = c_a$$

where c_a may be, in general, any function of time. It is important to emphasize that this relation implies the full activity of the hydrogen ions once they have diffused through the boundary layer.

Upon transformation, with the assumption of zero initial conditions, the boundary layer diffusion performance function may be written;

$$[PF]_{\text{diff}} = \frac{C}{C_a}(s) = \frac{1}{(1 + \tau_2 s)}$$

where C and C_a are in the complex s domain and $\tau_2 = \bar{C}/KA$ is the time constant associated with boundary layer diffusion.

Second-order function

Combining the two first-order lags gives the overall rate controlling mechanism of the glass electrode in a flowing solution:

$$PF = \frac{C}{C_i}(s) = \frac{1}{(1 + \tau_1 s)(1 + \tau_2 s)}$$

where C_a is assumed to be equal to C_o , which implies that perfect mixing in the flow cell is achieved. Thus, the potential produced by hydrogen ions on the glass surface is

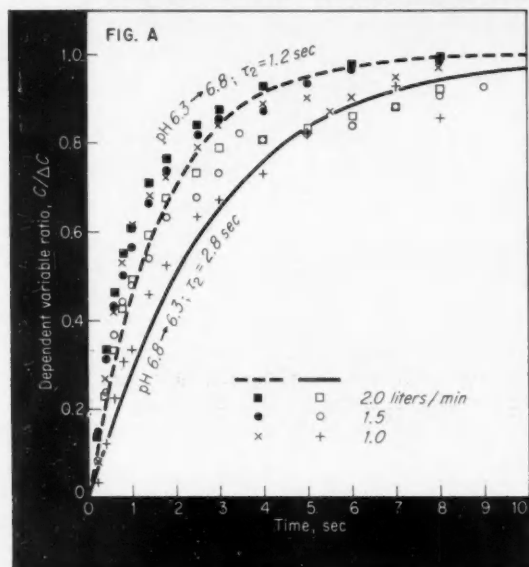
$$E(t) = -\text{Log}_{10}[\mathcal{L}^{-1}\{PF\} \times C_i(s)]$$

HOW THE TESTS WERE CONDUCTED

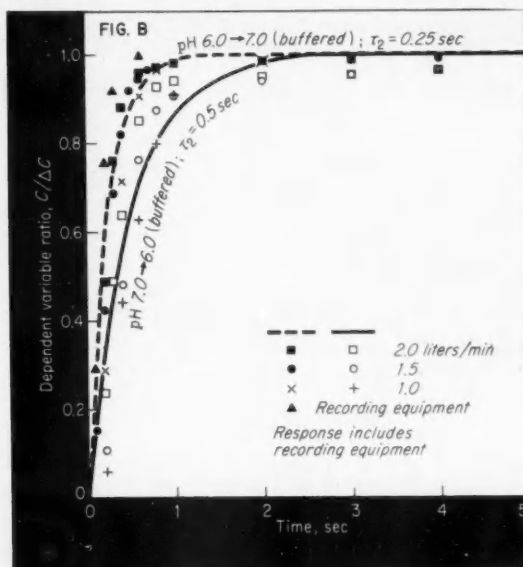
A continuous flow system for producing and recording step and square pulse changes of pH in aqueous solutions was set up as shown in Figure 3. Test solutions, consisting of distilled water with a pH value of 6.8 and a mixture of distilled water

Experimental Dynamic Responses of pH Electrode

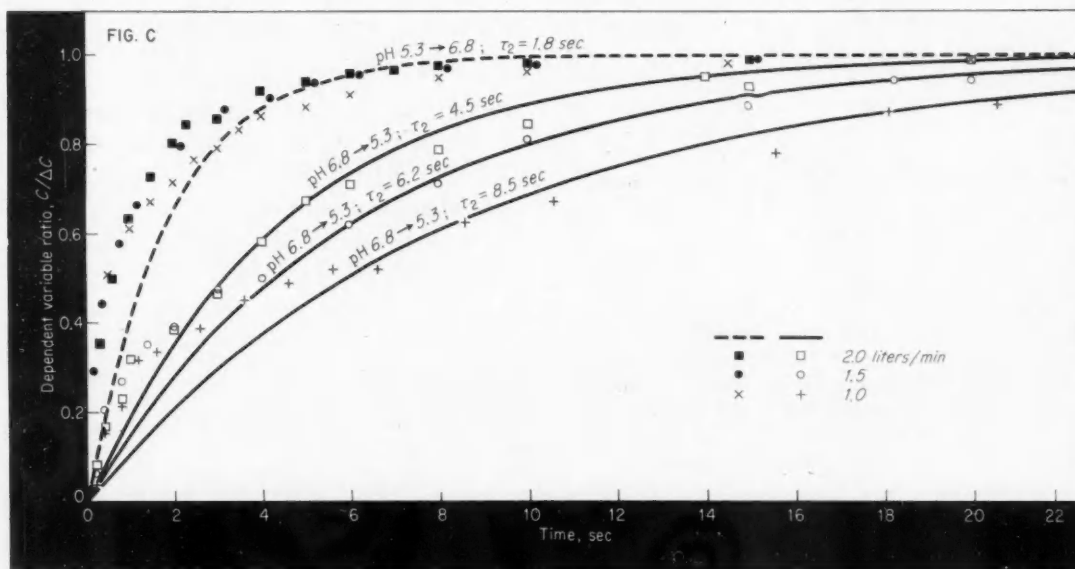
SPECIAL FLOW CELL; MINIMUM MIXING



0.5 pH CHANGE. Best-fit first-order curves indicate that response is independent of flow rate and mixing effect is not discernible. Only the direction of the pH change affects the time constant value.



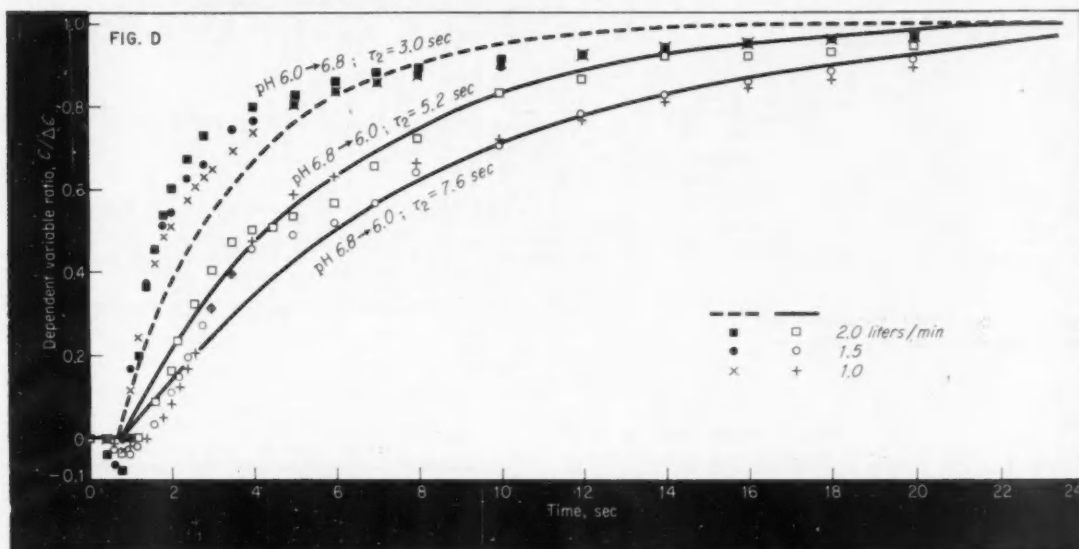
BUFFERING (1.0 pH CHANGE). Test data fits first-order response. Although pH change is larger, buffering makes electrode respond even faster. Effect of direction of pH change is again much in evidence.



1.5 pH CHANGE. At a larger pH change the responses are still first-order since minimum mixing occurs. At all three flow rates, going from pH 5.3 to 6.8, the time constant of 1.8 sec is so small that the effect of differing film thicknesses cannot

be discerned. However, going from pH 6.8 to 5.3 results in three different, larger time constants. Within experimental error, the time constants increase in proportion to the film thickness, see table on p 140.

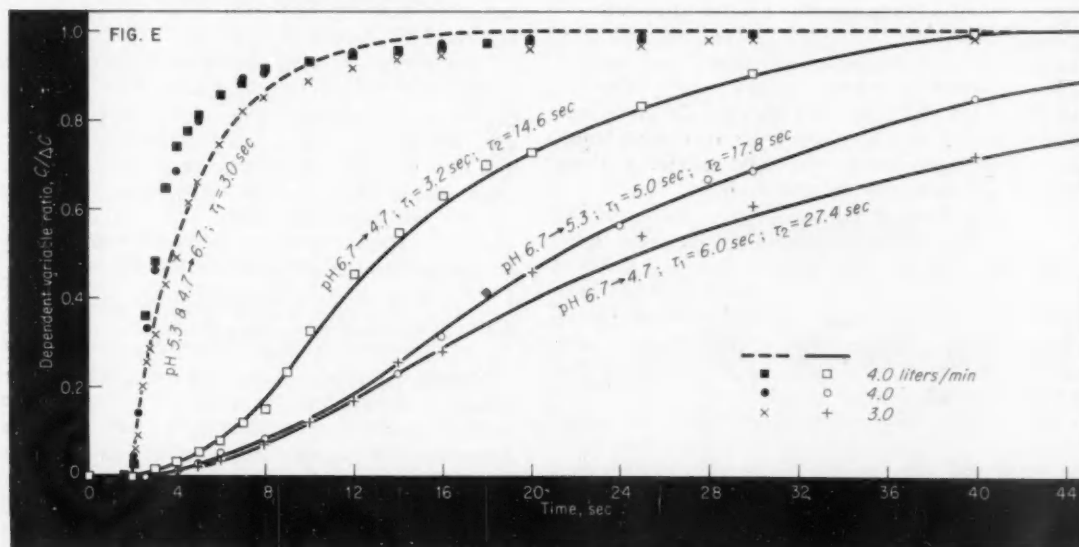
L&N PLASTIC FLOW CELL



Because of larger internal cell volume and irregular flow paths, the glass electrode responses are more complex and the effect of mixing is becoming evident. For comparison, the data averaged as first-order time constants. Again, the direc-

tion of pH change affects the time constant. The effect of film thickness is about the same at flow rates of 1.0 and 1.5 liters/min, but different at 2.0 liters/min. No explanation has been derived for the initial negative-going response.

L&N PYREX FLOW CELL



In this even larger cell, the effect of mixing becomes readily noticeable. Test conditions and data associated with the top curve indicate that the response is primarily attributable to mixing. The diffusion time constant is not discernible when

going from acid to water. But going from water to acid (three lower curves) shows the predominant effect of flow rate on the mixing time constant τ_1 , and of flow rate (hence film thickness) and pH change on the diffusion time constant τ_2 .

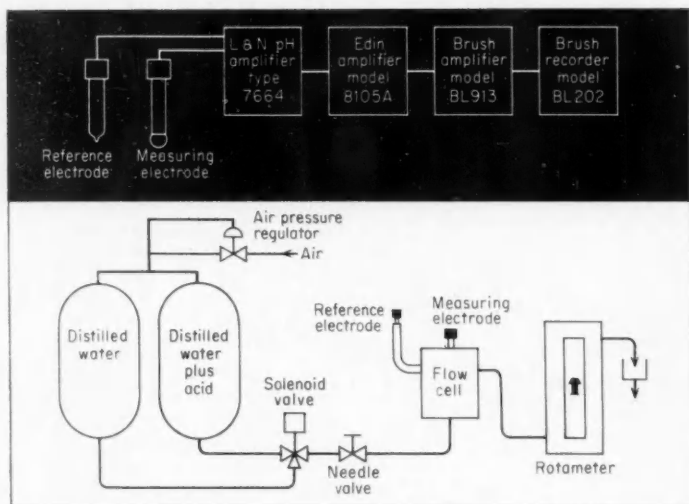


FIG. 3. Experimental flow system and measuring and recording equipment.

and perchloric acid with pH values ranging from 6.3 to 4.7, were mixed in pressure vessels and allowed to reach room temperature equilibrium. A test was run with a buffered solution, buffering providing a large amount of undissociated weak acid that acts as a reservoir of hydrogen ions. This reservoir rapidly replenishes ions that migrate into the electrode's surface. This increases diffusion rate and reduces effective film thickness, thereby—according to the electrode's mathematical representation and to one test—speeding up dynamic response.

An air pressure regulator maintained the pressure vessels at 20 psi so that changes in the level of the vessels would have negligible effect on flow rates.

Step and square pulse changes in solutions were generated by a small-capacity three-way solenoid valve, followed by a close-coupled needle valve for adjusting flow. Solution flow rates to 2.28 liters/min were measured by a rotameter. To determine larger flow rates, the solution was collected for a given interval and measured volumetrically.

The glass electrode used in these experiments was a Leeds and Northrup standard commercial electrode, No. 1199-30. The reference was an L&N No. 1199-31 reference electrode modified with a stand-pipe arrangement so that the KCl solution would have sufficient pressure head to flow through the liquid junction rather than be contaminated by the flowing test solution.

The dynamic response of the electronic recording equipment was determined by both direct frequency response and step input testing. Results indicated that the electronics could be represented by a second-order response having a damping factor of 0.7 and a natural undamped frequency of 11.3 rad/sec. Except as noted in Figure B, p. 138, the electronics response was fast enough to be negligible compared with electrode response.

Dynamic response tests were conducted on three

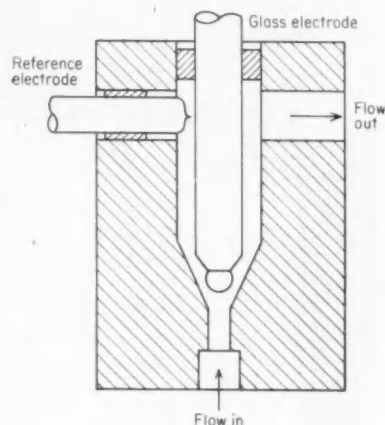


FIG. 4. Special flow cell for minimum mixing.

ESTIMATED BOUNDARY LAYER THICKNESS ON GLASS ELECTRODE IN SPECIAL CELL

Flow, liters/min	Velocity, ft/sec	Estimated boundary layer thickness, cm
1.0	3.8	6.13×10^{-3}
1.5	5.08	4.30×10^{-3}
2.0	7.63	3.32×10^{-3}

pH flow cells, one special cell, Figure 4, having negligible internal volume and known internal dimensions, and two industrial types exhibiting larger volume and more mixing. The two industrial flow cells were the L&N type 7780 plastic flow cell and the L&N type 7766 Pyrex flow cell.

Careful consideration was given to design of the special flow cell. By proper placement of the glass electrode, the annular cross section and thus the fluid velocity could be determined. Using theory and data given by McAdams (Reference), the film thickness on the glass electrode at various flow rates was estimated, see table above.

All pH response records were converted to hydrogen ion concentration and normalized to:

$$DVR = c/\Delta c = \text{dependent variable ratio}$$

where c = hydrogen ion concentration change

Δc = maximum excursion of hydrogen ion concentration

Figures A through E, pp. 138 and 139, show the results of the dynamic response tests of a glass electrode in three types of flow cells. Although nonlinearities and unexplained behavior do exist, the responses verify that mixing in the flow cell, direction of pH change, magnitude of pH change, and film thickness all play a significant role in time lag associated with the transient response of glass electrodes.

REFERENCE

HEAT TRANSMISSION, W. H. McAdams, McGraw-Hill Book Co. New York, 1954, p. 154.

Pulse Generator Controls Propeller Speeds

FRANK A. McKENNA, Wheelock Signals, Inc.

Error signals are converted to distinct output increments by the pulse generator. This electro-mechanical device provides stability in control systems where precise synchronization is needed.

For smooth handling and safety, multiengine propeller driven aircraft must have all engines carrying equal loads, so all must turn at the same speed. In flight any number of variables can cause variations in engine speed; thus constant automatic monitoring is necessary. When Curtiss-Wright built the engine for the Air Force C124, it used an engine speed control system that constantly compares each engine's speed with a reference. If there is a difference, a corrective signal goes to the engine's pitch control motor. Slight variations in propeller pitch will then return the engine to proper speed.

This control method has been used before, but this particular system has a unique stabilizing feature. Between the system's error detector, which causes the corrective pulse, and the pitch motor, which receives this pulse to make corrections, is a pulse generator. This generator, made by Wheelock Signals, Inc., receives each error signal and changes it to a 100-millisecond pulse before it goes to the pitch motor. The frequency of this 100-millisecond output pulse is proportional to error input frequency. In this way, large speed errors produce a rapid or constant correction signal, but small errors produce a very small correction. The end result is a stable system capable of finding the setpoint in one smooth operation without overcorrection.

The generator is made up of a power supply, a master relay, and two slave relays, each slave with an RC network in parallel. The generator's circuit (Figure 1) has two loops: one activated by an overspeed condition, and the other by underspeed. Each loop uses the same master relay but has its own slave relay and RC network. When an engine gets out of synchronization, the error causes a commutator to rotate. Speed of rotation is proportional to the magnitude of the error. The commutator makes and breaks the contact of the generator's 28-vdc circuit to ground, producing the input error pulse. Make-break time of the relays plus the RC time constant are arranged to give the 100-millisecond output pulse when energized by the error pulse. The delay built into the master relay controls the amount of charge the RC network will get. The RC network, in turn, controls the closed time of the slave relay. The slave relay closed time is the duration of the output pulse.

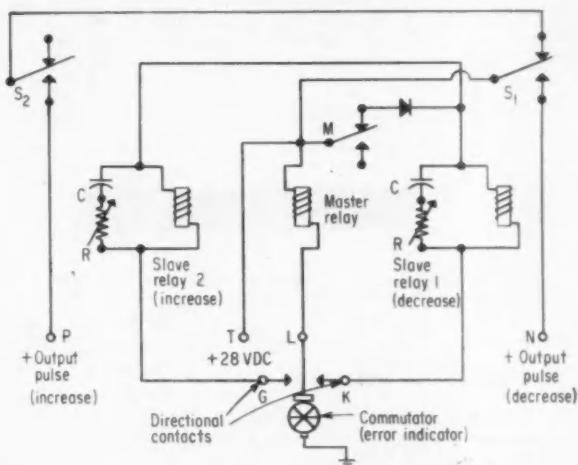
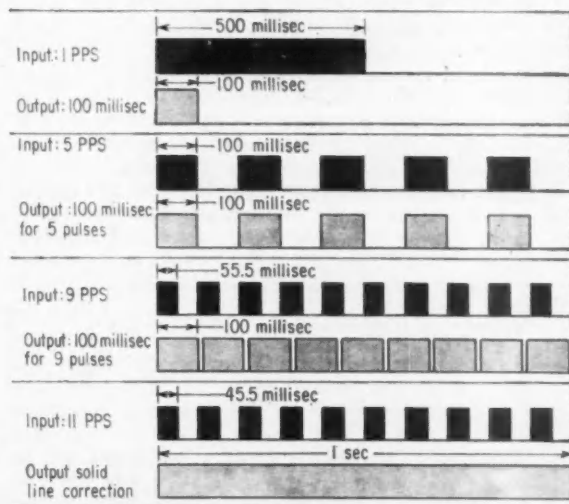


FIG. 1. Constant pulse generator.

FIG. 2. Input and output pulse characteristics. In each case input energization is 50 percent. This means the commutator which causes the error signal has conducting and nonconducting segments of equal width. So, if the commutator rotates at a constant speed, these segments will make and break at a constant rate, causing circuit on time to equal off time for any given period (such as one 500-millisecond pulse with a 500-millisecond break or two 25-millisecond pulses with two 25-millisecond breaks).



Code	
A	Slave relay operate time
B	Master relay break time
C	Master relay release time
D	RC network charging time
E	RC network discharge time
F	Energization or output pulse
G	Slave relay release time
H	Commutator contacts or input pulse

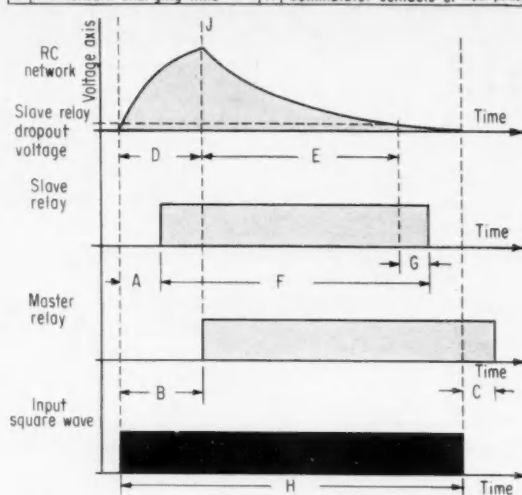


FIG. 3. Operating sequence of the generator circuit. Voltage is plotted against time for four principal circuit operations.

How output pulses are generated

Figure 2 shows input and output pulses at four stages of a typical correction sequence. The bottom of the illustration indicates a situation of large error, with input frequency greater than 10 pulses per sec. Since the generator tries to respond to each input pulse with a 100-millisecond output, there is overlap, resulting in a constant correction signal. Now as the pitch motor makes corrections, commutator rotation slows and at 9 pulses per sec (indicated third from the top) the generator, responding with 100-millisecond pulses, gives a closely spaced output. With even less error the 100-millisecond correction pulses are farther apart. Finally at the top of the chart, error between propeller speed and reference speed is very slight, making the commutator turn very slowly and causing a long input pulse. The generator still produces only a single output of 100-millisecond pulse for this long input. When the speed is almost exact, the input signal will get even longer, but with a single 100-millisecond correction pulse. This assures accurate correction with no chance of overshoot. As long as input remains below a certain preset frequency, the square output wave frequency varies in direct proportion to input frequency. In this case, 10 pulses per sec is the limiting frequency. A higher frequency would of course cause a constant correction signal. Under normal operating conditions maximum error in a 100-millisecond pulse will be about 2 percent.

System operation

In operation the pilot sets a reference alternator that sends pulses proportional to the desired engine speed to a speed comparator on each engine. Alternators on each engine send pulses proportional to actual engine speed to their respective comparators. If an engine is over or under speed, the signals from the reference and engine alternators will not synchronize,

causing an armature in the comparator to rotate. With the error detected by the rotating armature, a signal must then be introduced to the pulse generator to correct the error. This is done through a commutator attached to the armature shaft. The commutator, rotating with the armature, makes and breaks contact in the generator circuit, initiating corrective pulses.

Since there are two error conditions, overspeed and underspeed, there are two loops to the generator circuit, (see Figure 1). The windings are arranged so the commutator will rotate one way for overspeed and the opposite way for underspeed. Brushes sense the direction and ground one or the other circuit loop.

The energizing sequence of an individual pulse is illustrated in Figure 3. An error signal H, caused by the commutator, first energizes the circuit. (Symbols refer to Figure 1 or Figure 3.) Capacitor C then begins to accumulate charge D through rheostat R to ground. Charging time depends on the break time of the normally closed contacts of master relay M and the RC time constant. The normally open slave relay closes after operate time A, provided the charge on the capacitor exceeds its pull-in voltage. With the slave relay closed, the output or corrective pulse goes to an actuator at point N, which in turn varies propeller pitch. When operate time B has passed, the master relay opens its normally closed contact, cuts off the power, and stops capacitor charging at point J. The time the slave relay will stay in operation depends on the discharge time constant $(R + R_{coil}) C$, the maximum voltage the capacitor reaches, and break time and dropout voltage of the slave relay. Variation in any of these factors will change the duration of the output pulse.

Output pulse = (master relay break time) - (slave relay operate time) + (RC network discharge time) + (slave relay release time) or, referring to Figure 3,

$$F = B - A + E + G$$

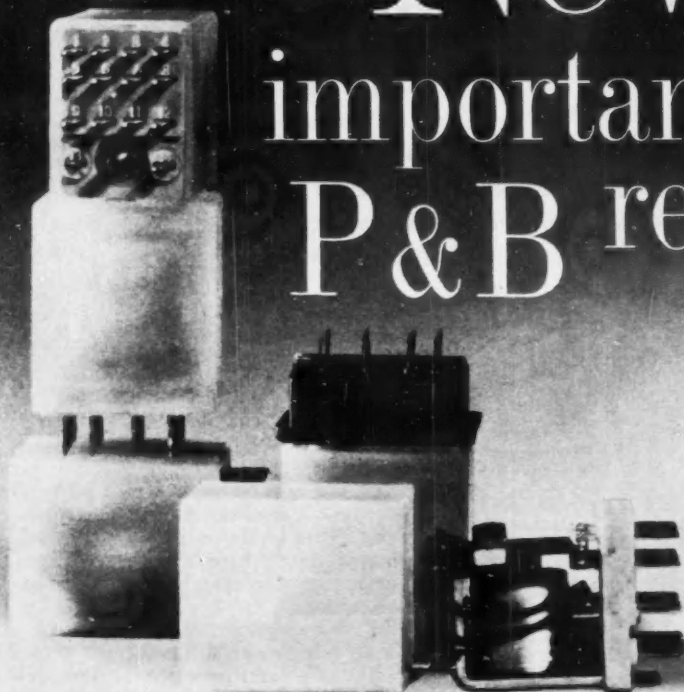
Following pulses will go through the same sequence until the correction is made and the commutator stops turning. It makes no difference if the commutator stops on a conducting or nonconducting segment. On a conducting segment, the master relay will stay operative, preventing an output pulse. A nonconducting segment will open the circuit.

In the design of the generator, components can be selected to produce a great output signal variety. Once the relays are selected, the make and break times are fixed. The only other variable is the RC network which affects about 85 percent of the output pulse time.

By regulating the rheostat of the RC network, the pulse duration is accurately controlled. It should be pointed out that the situation illustrated in Figure 3 is that which the generator will be required to handle most commonly. Should there be two or more distinct pulses during the time H now designated by a single pulse, constant correction would result, since charge J would not have enough time to decay below slave relay dropout voltage before a new charge was introduced to the RC network. Any signal longer than that indicated by H would have no effect, since the RC network could gain no further charge to operate the slave relay.

Maximum input frequency is 180 pulses per sec. Because of the flux buildup, the master relay will remain continuously in an operating position above 180 pulses per sec.

a New and important P & B relay . . .



KHP SERIES SHOWN ACTUAL SIZE

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This small, 4-pole relay has the happy faculty of maintaining its original operating tolerances over an exceptionally long life. Example: tests (by customers!) show this relay has variations in electrical characteristics of less than 5% after more than 100 million operations.

But that's far from all. This is a *small* relay . . . about a one inch cube. This relay is easy to install using the conveniently spaced solder lugs or a socket. Thus you save time and production costs. This relay is versatile . . . its 4PDT contacts will switch loads from dry circuit up to 3 amperes. This relay—well, why not order samples and see for yourself! Order today from your P & B representative or call us at Fulton 5-5251, in Princeton, Indiana.

KHP SERIES SPECIFICATIONS

CONTACTS:

Arrangement: 4 Form C, 2 Form Z.

Material: $\frac{1}{16}$ " dia. Silver standard. Silver cadmium oxide and gold alloy available.

Rating: 3 amps @ 30 volts DC or 115 volts AC resistive for 100,000 operations.

COILS:

Resistance: 11,000 ohms max.

Temperature: Operating Ambient: -45°C . to $+70^{\circ}\text{C}$.

Power: 0.5 watts min operate @ 25°C . 0.9 watts nom. @ 25°C . 2.0 watts max. @ 25°C .

TIMING VALUES:

Nominal Voltage @ 25°C .	Max. Values
Pull-in time	15 ms
Drop-out time	5 ms

INSULATION RESISTANCE: 1500 megohms min.

DIELECTRIC STRENGTH:

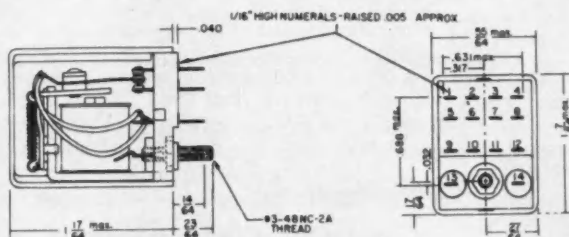
500 Volts RMS 60 cycles between contacts.
1000 Volts RMS 60 cycles between other elements.

MECH. LIFE: In excess of 100 million cycles.

SOCKET: Solder lug or printed circuit terminals.
Available as accessory.

DUST COVER: Standard.

TERMINALS: Solder lug and taper tab.



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The Photoconductive Cell

-New Tool for Light Measurement

Photoconductive cells, once forsaken as light detectors, are now being used in many photovoltaic applications. Improved stability, greater voltage range, and increased sensitivity may prove the photoconductive cell superior to many existing light sensing devices.

ROBERT A. FARRALL, Instrument Dept., General Electric Co.

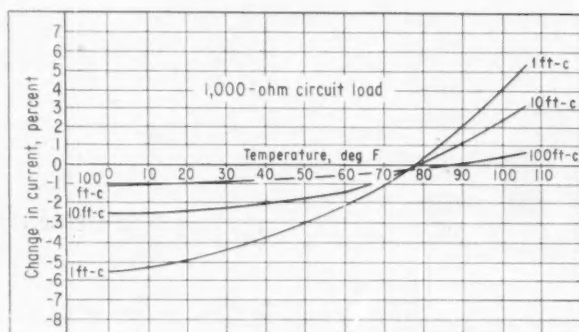


FIG. 1. Temperature vs current change for 1, 10, and 100 ft-candles.

CHARACTERISTICS OF COMMERCIALLY AVAILABLE PHOTOCONDUCTIVE CELLS

	CdS	CdSe
Peak spectral response	5,000-6,200 Angstroms	6,900-7,400 Angstroms
Sensitivity resistance* at		
10 ft-c	5-50 kilohms	1.2-12 kilohms
100 ft-c	1.5-15 kilohms	0.5-5 kilohms
Dark resistance	1-1,000 megohms	1-1,000 megohms
Time response—time to reach 75 percent of reading at 10 ft-c	0.05-0.20 sec	0.005-0.05 sec
Operating voltage	1-300 volts	1-300 volts
Maximum operating temperature	160-185 deg F	160-185 deg F
Minimum operating temperature	-50 to -120 deg F	-50 to -120 deg F
Maximum power dissipation	0.05-0.5 watts	0.05-0.5 watts
Hermetic sealing	Yes	Yes

*Sensitivity may be tailored to particular application by cell size and contact configurations

Improved characteristics mean that the photoconductive cell can now be applied to a wider range of jobs than formerly possible with more common photovoltaic cells. Many of the properties of this cell, which had prohibited its use, have been changed through better manufacturing techniques, resulting in a more versatile light detector.

The cell is not self-generating, as are other light sensing cells; rather its resistance changes when it is exposed to light. As light intensity increases, cell resistance decreases, making current through the cell a function of light intensity.

Although the operating principle of the photoconductive cell has been known for some time, practical applications were impossible until designs were improved recently. Early cells used silver contacts, which did not give good ohmic contact in low voltage ranges. Now that the silver contacts have been replaced by indium and tin contacts, almost any voltage within the dissipation and insulation limits of the cell can be used.

Stability has been improved by hermetically sealing cells in glass enclosures similar to those used for vacuum tubes. Previously, the cells had been potted in plastic, which water vapor and other toxic agents could penetrate and so attack the photoconductive material.

Poor sensitivity, for which the photoconductive cell had been known, has now been remedied by improved doping techniques. Cells now have good light to dark ratios and sensitivity. For example, one type of cell has a dark resistance of 500 megohms, while at 0.05 ft-candles, its resistance goes down to 200,000 ohms.

A further look at the features of the photoconductive cell may point up some areas in which it can most profitably be used. A summary of the characteristics of a typical cell can be seen in the table.

Advantages

Characteristics of the photoconductive cell that are advantageous in applications are:

Ability to respond to low light levels—This is due to the nearly unlimited sensitivity of the cell plus its ability to operate at high voltage (300 volts plus). On the

CELL THEORY AND CONSTRUCTION

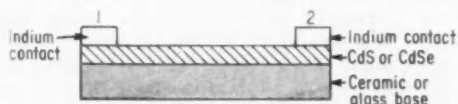


FIG. A. Construction of typical photocell. The photocell resistance is measured between contacts 1 and 2. Therefore as the contacts are moved closer, the resistance will decrease due to the shorter path between contacts.

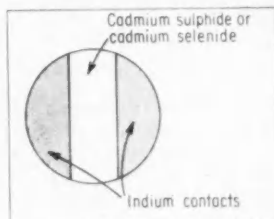


FIG. C.
Most common contact configuration.

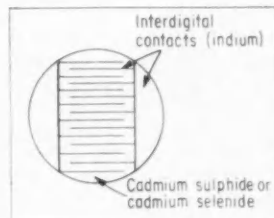


FIG. D.
Interdigital contacts give effect of many photoconductors in parallel, thus lowering resistance substantially.

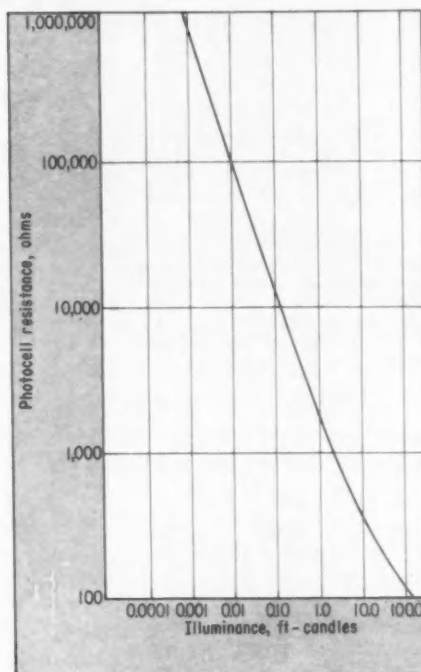


FIG. B. Plot of resistance vs illumination for a typical photocell.

A typical cell available today would be composed, in most cases, of a support disc or wafer which has been coated with a thin film of cadmium sulphide or cadmium selenide, Figure A. There will be at least one set of contacts resting on top of the coated wafer. Variation in resistance of the coating between contacts and wafer produces a change of current through the cell.

The physical picture of this change may be explained by semiconductor theory. When a photon impinges on the surface of a photoconductive cell, an electron hole pair is created. The electron pair rises to the conduction band where the hole recombines, but the electron continues to move, causing a conduction current. This conduction current, flowing through the photoconductive material, causes the change in resistance.

As the number of photons increases (greater light intensity), more electrons are freed and resistance further decreases. With less light, resistance increases. Figure B shows the relation between resistance and illumination.

There are several types of contact configurations currently used on photoconductive cells which give the cell greater design flexibility than the photovoltaic type. A typical cell has two contacts, with the resistance being measured across them, Figure C. This type can be manufactured more easily. It is used where extreme sensitivity is not necessary or where the light source is very narrow.

There are also interdigital cells which have many small interlocking contacts, Figure D. This cell is recommended for jobs requiring maximum sensitivity or applications using a broad light source. Each contact becomes a small resistor in parallel with the others. By increasing the number of parallel contacts, the sensitivity is greatly increased without changing the cell area. Should a particular design require a cell of a certain area, in most cases a new contact mask with finer, more closely spaced contacts is all that is needed. With selenium photovoltaic cells this is not possible.

other hand, selenium photovoltaic cells have a limited sensitivity. Obtaining milliampere outputs from a selenium cell requires hundreds or thousands of foot-candles. The only limit on the output of the photoconductive cell is its designed power rating.

Small size—This allows for instrument miniaturization. In devices where the viewing angle of the light detector is important, small viewing angles can be designed with a minimum of optical accessories. Exposure

meters are now available with acceptance angles or angles of view of only 2 deg. For example, light levels of 0.001 ft-candle can be measured with a cell whose active area is only 0.004 sq in.

Hermetic sealing—This has made the photoconductive cell virtually unaffected by environment. Cells have been run in temperatures from 185 deg F to minus 58 deg F with no adverse effects. Permanent change in cell output due to these temperatures was no more than

How Cells Have Been Used

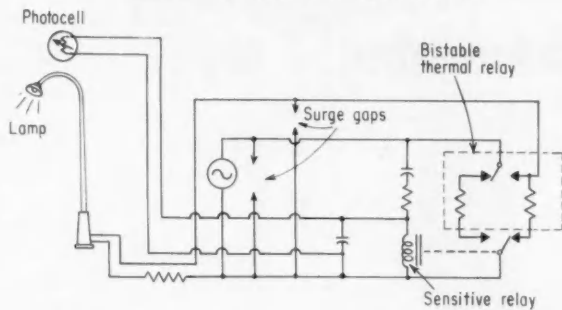


FIG. 2. Automatic street light switch. Circuit is shown in the daytime or off position. When light has diminished to a predetermined level, cell resistance rises and the relay is energized, in turn energizing the left heater. Light goes on when the heater has caused the bistable relay to trip. The same relay disconnects the heater as it turns on the lamp. At dawn the operation is reversed.

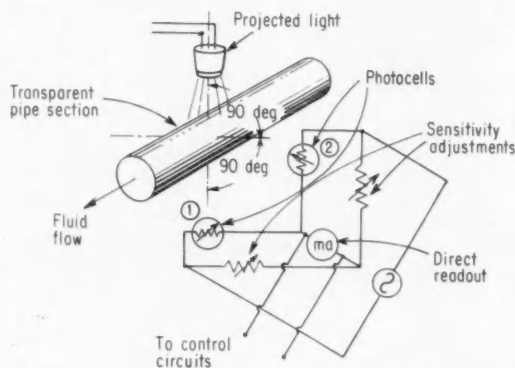


FIG. 3. A turbidimeter. Two photocells are located at right angles to each other on the outside of a transparent pipe carrying the liquid to be measured. A light source is projected directly at one cell and at 90 deg to the other. Cell No. 1 measures light transmitted through the liquid and cell No. 2 measures light scattered by the liquid. As the liquid becomes more turbid, cell No. 2 will receive more light. The cells' outputs are initially adjusted to balance the bridge circuit when liquid turbidity is some known value. Any deviation from the standard will unbalance the circuit.

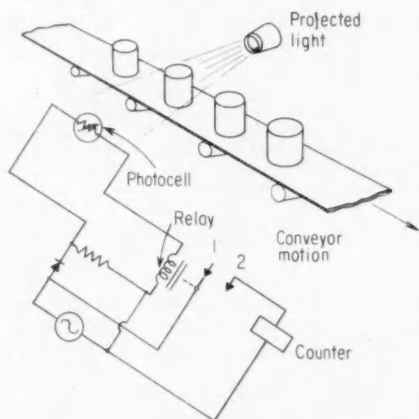


FIG. 4. Counter for assembly lines. Circuit is shown in normal position with photocell resistance low and relay energized, preventing current flow to counter. When an object passes between the lamp and the photocell, cell resistance increases, dropping out the relay and (position 2) energizing the counter. After the object has passed the circuit returns to normal. Cells are capable of counting light pulses up to 100 cps.

the change in a standard selenium cell subjected to the same temperatures. Selenium cells when hermetically sealed are three to five times more expensive and much larger than photoconductive cells.

As temperature increases photocell resistance decreases. The percentage of resistance change is a function of the light falling on the cell. Percentage change is illustrated in Figure 1, which is a plot of temperature vs change for 1, 10, and 100 ft-candles.

Voltage used can be ac or dc—Since the photoconductive cell can operate equally well on either, there is no need to design a stabilized dc amplifier since an ac amplifier can be used. Cell outputs are often high enough to operate relays without amplification.

Disadvantages

There are, however, some items on the debit side, namely:

Cost—Photoconductive cells cost about \$1.25 when bought in quantity and \$3.00 in small quantities. Since most cells are hermetically sealed they cannot compete with nonsealed selenium photovoltaic cells which cost only 30 to 50 cents, but as noted above, hermetically sealed selenium cells are much more costly than photoconductive cells.

Lack of data—Because they have been in widespread use only a few years, there is limited operational data available on photoconductive cells. Accelerated life tests indicate that the photoconductive cell will be more than adequate for most measuring applications; however, difficulties such as cell drift, which may be caused by impurities sealed in during manufacture, have yet to be thoroughly investigated.

Need for outside power—The photoconductive cell is not self-generating, so it needs an outside power source. In most control systems this would not be a disadvantage since power is readily available, but in applications such as an exposure meter, the cell might be inconvenient since batteries would be required.

Successful applications

The photoconductive cell has already been applied successfully in industry. Three such applications are illustrated in Figures 2, 3, and 4. They show an automatic street light switch, a turbidimeter, and an assembly line counter, respectively.

If colored filters are placed over the active area of the cell, it can discriminate between colors. In the same manner it can also become an indicator of color density.

Temperature controllers also utilize the photoconductive cell. When the temperature indicator's pointer reaches some preset limit, it blocks a light source, causing a relay to trip. As these applications illustrate, the job need not be an on-off variety because the cell can respond to a continuously varying light source.

The fact that light puts no force on the object being measured is probably the major advantage of using light in control systems. Direct measurement is made possible which could be done in no other way. Wherever the transmission, reflection, or absence of light can be used to measure a parameter directly or indirectly, photoconductive cells can be applied to measure and control the product with virtually no limit to the applications.



Collecting Process Data for an On-Line Digital Computer

THE GIST: When a digital computer is used for on-line control, process data must be supplied in a form compatible with computer input requirements. Data in analog form must be scanned, zero-suppressed, amplified, converted to digital form, and sequenced into the computer input register. The equipment which does all this is called a data collection system or data gathering system. This article describes an inexpensive data collection system developed and used by Phillips with a RECOMP II computer for on-line control of a thermal cracking furnace. The on-line service factor of this system was 100 percent during a seven-month program.

**D. A. FLUEGEL, E. D. TOLIN,
and J. R. PARSONS**
Phillips Petroleum Co.

A digital computer, RECOMP II, has been used for on-line control of a thermal cracking furnace in Phillips ethylene plant at Sweeny, Texas (Ref. 1). RECOMP II is designed to do engineering calculations (Ref. 2) and has no input equipment specifically provided for on-line collection of process data. Thus, a data collection system was developed and built to use RECOMP II for direct process control. The system translates analog signals from process transducers into digital signals whose form and timing are compatible with the computer's input characteristics (Ref. 3).

The computer program for the thermal cracking furnace requires data from 23 process variables: 16 thermocouple measurements, and seven pressure measurements represented by dc millivolt signals from pneumatic to electric (P/E) transducers. Some of the thermocouples, the cold junction, and all of the P/E transducers were a part of a data collection system already in use for other purposes. But existing systems did not translate data to the digital code required for the computer, so a parallel independent data collection system was designed.

Figure 1 shows the data collection system. Individual signals from process variable transducers pass through input filters to the analog sequencer or scanning device. The filters equalize power line noise on the signal input lines, isolate input circuits of the two parallel data systems, and limit input change rate to the amplifier.

Stepping switches scan the input signals at 1 point per sec. This rate is adequate considering

that only 23 variables are scanned and that the problem solution time in the computer is about thirty minutes. Scanning rate is low enough that a single, limited-bandwidth amplifier can amplify low level signals from the analog scanner.

The input signals are zero-suppressed at the input to the amplifier. Range or span is set by changing the amplifier gain. An analog-to-digital converter (ADC) changes analog signals from the amplifier to the straight-binary digital code used by the computer. This reduces computer time and storage which would otherwise be needed for code conversion. The ADC converts dc inputs to a resolution of ten bits.

A digital sequencer then processes the digitized data from the ADC and transfers it to the computer. Because the computer input register can accept only five simultaneous bits of binary data a complete binary input word of ten bits from the ADC must be transferred serially in two groups. (In addition a digital clock with an eleven bit output requires three serial groups of five parallel bits.)

Data gathering systems are simpler than data loggers

There is a basic difference in design philosophy between a data logger and a computer data gathering system. A data logger provides information, possibly computed information, in engineering units with the decimal point properly located. A computer data gathering system, however, must provide a digital computer with meaningful information having the highest possible resolution. This information need not be meaningful to engineers, but only to the computer with its stored program. The computer converts the high resolution information to engineering units without additional hardware, thus taking advantage

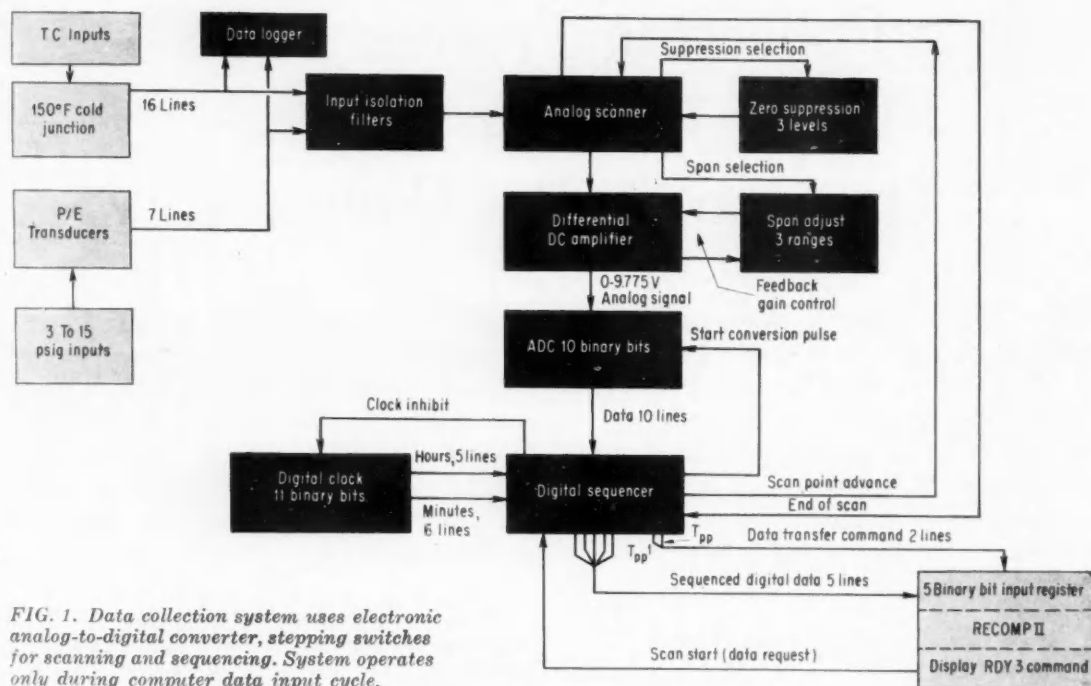


FIG. 1. Data collection system uses electronic analog-to-digital converter, stepping switches for scanning and sequencing. System operates only during computer data input cycle.

of the computer's speed and flexibility to keep simple the data gathering hardware.

The limit on system resolution is the noise output of the low level amplifier or the length and accuracy of the binary word out of the analog-to-digital converter. The total output voltage span of the amplifier must be properly used on each input variable to get the best signal-to-noise ratio out of the amplifier. This requires zero suppression at the input to the amplifier and adjustment of the amplifier gain. For example, a signal which varies from 10 millivolts to 20 millivolts should have 10 millivolts zero-suppressed, which leaves a 0 to 10 millivolt signal for input to the amplifier. If the maximum output voltage range of the amplifier is 0 to 10 volts, the amplifier gain should be set at 1,000, so that the full range represents the change in the input variable. If the input signal is not zero-suppressed a maximum gain of 500 can be used and the meaningful information would be compressed between 5 volts and 10 volts at the amplifier output.

The same reasoning applies to the ADC to insure maximum possible resolution of the information at its output: the meaningful information should be properly zero-suppressed and spanned to make the analog input to the ADC vary over its maximum available range.

Step-by-step through the system

• **Isolation filters.** Figure 2 shows input filters between the transducer outputs and the analog scanner. The input filter time constant was set

at approximately 1.8 sec, based on estimates of the rate of change of transducer outputs and the errors introduced by switching of the transient filter at the amplifier input. With the network the parallel data logger has an input error of

$$[0.46 V (e^{-0.8t} - e^{-108t})] \text{ millivolts,}$$

where V is the transducer open circuit output voltage in volts. For the worst case, a zero to full scale change in signal level between adjacent switch inputs, a maximum instantaneous error of 0.04 percent of full scale occurs approximately 32 millisecc after the switch is closed.

• **Analog scanner and amplifier.** The stepping switch which sequences the analog signals to the amplifier input also selects the proper zero suppression and amplifier gain.

The transducer signals are amplified by a dc differential amplifier of high input impedance, low noise level, and rather narrow bandwidth. The differential input feature contributes greatly to increased system accuracy by reducing noise introduced on the signal input lines from 60 cps power lines and equipment. Over-all system noise is about 0.1 percent of full scale output. A separate instrument ground used for all equipment also contributes to the low noise level (Ref. 4).

The full scale signals from the various transducers cover a range from 12.6 to 29.08 millivolts, so it is necessary to scale these signals to fit the full range of the ADC. A gain (span) selection circuit in the amplifier does this scaling. The feedback network around the output section of the differential amplifier was modified to permit selec-

tion of the exact gain required to raise each maximum signal level to 9.775 volts at the ADC input. These signals are then binary coded from 0 to 1,000 at the ADC output.

• *Analog-to-digital converter.* The input filter time constant (1.8 sec) limits the maximum rate of change in signal voltage that can exist at the ADC input (Ref. 5). Ambiguous conversions by the ADC are minimized because the conversion time is fast enough so that the voltage change during a conversion period is less than the least significant bit. This eliminates the need for sample and hold circuitry.

The initial rate of change for a full scale transient at the transducer output is

$$e_o = E(1 - e^{-t/RC})$$

in which:

E = full scale ADC input, 9.775 volts
 t = 50×10^{-6} sec, the conversion time of the ADC
 RC = 1.8 sec

$$e_o = 9.775 \left(1 - e^{-\frac{50 \times 10^{-6}}{1.8}} \right) = 270 \text{ microvolts}$$

This is the maximum voltage change which can occur during a conversion interval and represents

$$(270 \times 10^{-6} / 9.775) (100) = 0.00275 \text{ percent}$$

of the full ADC range. Thus the data is converted accurately without sample and hold techniques.

• *Digital clock.* A system clock tells the computer in binary code the time when each data scan is completed. The hours word is generated by a stepping switch and is represented by five binary bits for 0 through 23 hours. A minutes word consisting of six binary bits representing

minutes 0 through 59 is generated by two more stepping switches. Clock advance pulses are supplied by 1 rpm synchronous timer operating from the 60 cycle power line. An inhibit pulse applied to the clock by the digital sequencer prevents clock advance during time-signal read-in to the computer. In this case the clock advance pulse is stored until read-in is completed.

• *Digital sequencer.* The digital sequencer breaks up each data word from the ADC into groups of five bits each and commands the computer to transfer each five bit group into its input register. Three groups of five bits each are transferred to computer storage through the input register for each scanner position. This is done to accommodate the 11 bit word for hours and minutes generated by the digital clock. The digital sequencer is started initially by a request for data from the computer (command RDY3). The entire data collection system is therefore active only during the computer input data routine during which the computer is programmed to receive a discrete number of data words. The analog scanner and ADC are controlled by the digital sequencer.

Figure 3 is a simplified diagram of the digital sequencer, which times the entire data collection system. Data are transferred to the computer by relays (RY1 to RY5) operated from five bank levels on a 26-point stepping switch. The switch steps at 4 steps per sec and allows entry of the scanned data to the computer register at 1 data point per sec. Although only three steps of the sequencer are required for transfer of a data word, a fourth step is used to allow for amplifier transient response (setting time).

Connections from the ADC output register to

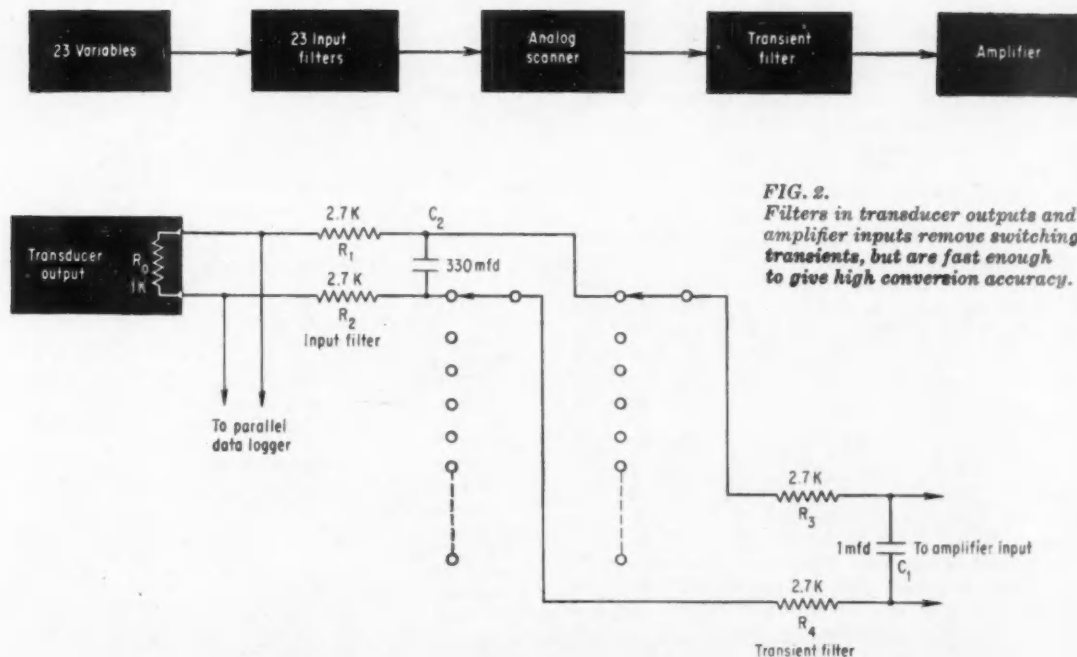


FIG. 2.
 Filters in transducer outputs and amplifier inputs remove switching transients, but are fast enough to give high conversion accuracy.

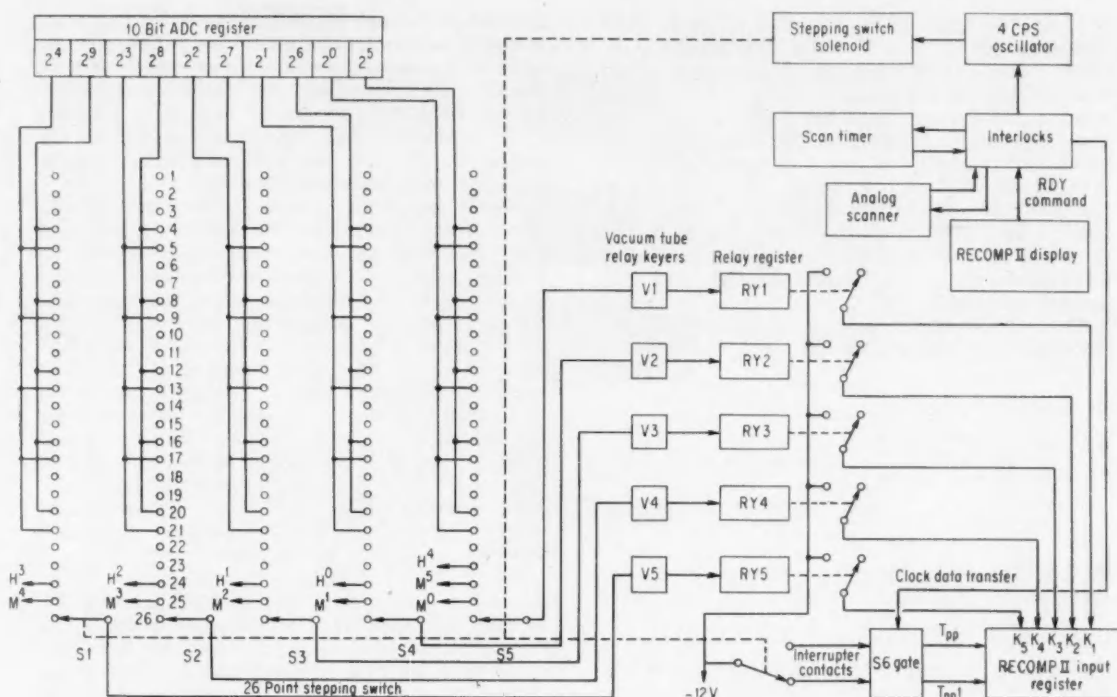


FIG. 3. Stepping switch and relay register in digital sequencer provide serial input to computer of 10-bit parallel output of analog-to-digital converter. Six cycles of this stepping switch are made to one of switch in scanner.

five switch bank levels allow five complete process data words to be transferred to the computer during one sequencer cycle. A thirty-first data word representing time in minutes and hours is transferred by switch positions 23, 24, and 25. Six cycles of the switch are used to transfer data for each cycle of the analog sequencer. This allows seven spare analog input channels. Clock information is transferred to the computer only when the analog reaches the thirty-first switch position and time is thus the last data word of a scan.

Since the computer input register interprets an open circuit as a zero, the relay register circuitry is arranged to transfer zeroes for all open connections on the stepping switch. Thus the five most significant bits of each process data word and the four most significant bits of each clock data word are always transferred as zeroes. This satisfies the requirement for transfer of 15-bit words to the input register.

A transfer pulse (T_{pp}) causes the data on lines K_1 - K_5 to be transferred to the input register. The transfer pulse is generated by the digital sequencer interrupter contacts and is gated by a sixth level on the switch (S6 gate). This pulse occurs just before each advance to the next switch point and is gated to the input register only on positions 3, 4, 5; 7, 8, 9; 11, 12, 13; 15, 16, 17; and 19, 20, 21; plus positions 23, 24, and 25 only if the analog scanner is on switch position 31.

Properly applied stepping switches are reliable

Reliability was a prime design objective for the entire data gathering system. All stepping switch contacts make and break dry circuits (no current). Vacuum tube keyers drive the individual relay coils and stepping switch solenoids to reduce arcing and increase the operating life of the switch contacts. All stepping switch contacts are gold plated. During a seven-month program the on-line service factor of this system was 100 percent.

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As K & M's Chief Engineer, George Chinn might be expected to be at least somewhat biased in his opinion of the valves we make. He isn't. Ask him about our products and he'll tell you that they're "not bad".

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More often than not, he finds a few unsuspected bugs. When he does, we are, honestly, almost glad. Not that we enjoy headaches or have anything against showing a profit. It's just that we'd rather find the flaws, if any exist, than have our customers find them. Makes sense, doesn't it?



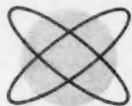
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Computers Centralize Inventory Control at Square-D

Square-D has made significant corporate changes during past years to get as much benefit as possible from newer and faster information systems. Punched card tabulating equipment was replaced over a year ago with two IBM 305 RAMAC computers which have cut the time lag between sales and actual production from more than eight weeks to less than one week. All sales records and the inventory levels of finished products and component parts in each warehouse and the Milwaukee factory are maintained only by the computer at Milwaukee. Up-to-date information is supplied by the computer to local offices. Two 1401s now on order will replace the RAMACs to cut inventory levels and shorten delivery times still further.

BRUCE CROSS

McGraw-Hill News Bureau

The Industrial Controller Div. of Square D supplies 12 warehouses and each warehouse serves four to 12 branch sales offices. Warehouses had maintained their own stock records for many years on punched card tabulating machines. Cardex file cards were kept for each stock item; the on-hand balance was updated whenever a sales office informed the warehouse of a sale. Sales offices also posted their own records under a general decentralization plan.

Company operations went smoothly for many years. Each warehouse kept separate records, and the Milwaukee plant still kept reasonable production levels. Early in the 1950's, however, sales volume increases brought problems into the open which had lain hidden in older operating methods.

When inventories dropped too low, warehouses sent requests for more stock to Milwaukee headquarters; but these requests were sporadic, and sometimes arrived too late to prevent a warehouse from running out completely of different items. Often, eight to 12 weeks passed before warehouse stocks were replenished; and, in the meantime, sales offices might have taken orders which could not be filled from stock.

Sales offices made detailed sales reports infrequently, simply because there was not enough time. Summary reports sent to Milwaukee helped, but did not contain enough information for management to plan a thorough production schedule far in advance.

Communications between company offices was slow and insufficient. A branch sales office unable to fill an order directly from one warehouse would have to order from Milwaukee—because on-hand

stock records were kept by each warehouse, the sales office had to overlook the possibility that other warehouses might have more than enough stock to fill the order.

The answer was faster computers

At the time Square-D decided to use computers, business had grown 13 times greater since punched card tabulating equipment first was used in 1943. It was plain that good customer service could not be maintained without drastic operating changes.

Square-D made two major decisions: a change from decentralized to centralized record-keeping, and a speedup of interoffice communication. All warehouses would send statistical information daily to Milwaukee instead of posting it themselves on their own books. Every sales office would send daily a copy of every new customer order to Milwaukee, even before the order was shipped.

These changes eliminated on-hand balance records which warehouses used to have at their fingertips, which scared many employees and brought a common complaint: "How can we operate if we don't have our records?" The question solved itself: because of computer speed and daily reports, it was necessary only to keep Milwaukee informed, and Milwaukee did the rest. But Square-D still had to convince employees that they could have confidence in RAMAC.

Square-D spent two years planning for its computer system, using two specially-trained employees to set up the programs. A stockroom was remodeled to house the computers, complete with air conditioning, temperature-humidity recorders, and acoustical tile. Management informed all employees about the computer and its job, and held frequent training sessions with all department managers and foremen who would be affected by the new information system.

The first of two 305 RAMAC computers was

delivered in November 1957, and programmed to control 30,000 finished products and component parts. Each of 4,000 finished products is stored by a four-digit stock number compatible with the RAMAC address code. Each of 26,000 component parts is represented by a five-digit number. Every item is associated with Milwaukee stock records (100 bits), cross-reference information (100 bits), warehouse stock (200 bits), and combination information (70 bits); all information for any one item is grouped on five memory disc tracks.

The number of finished products stored in memory was minimized by listing only basic product types. For example, two models of a motor starter—one with and one without pushbuttons—are not stored separately. Pushbuttons and some other optional features are usually installed at warehouses, not at the factory. This basic decision freed nearly 10 percent of the memory for additional work.

The second 305 was delivered in February 1960. Its program takes care of billing, cost of sales, sales statistics, and salaried payroll. Square-D hopes to let computers do factory payroll and general accounting in the near future.

Although the new information system has integrated sales and production, warehouse stock replenishment is the major area of improvement. Most large companies have warehouse replenish-

ment systems, but Square-D's computer program does the job so quickly that production can be tailored to sales.

Diagram shows stock control routine

The following hypothetical example describes how quickly this stock control and production planning system can react to an unusually large order. It also illustrates a premise which underlies the entire information system: everything starts with the computer. The steps can be followed in the flow diagram of Figure 1, which continues across the following pages.

Monday . . . Baltimore sales branch office receives order for 1,000 motor starters and all sales information is transcribed onto multi-part form. The order is sent to the Philadelphia warehouse which ships directly to customer. Two copies are sent immediately to Milwaukee headquarters.

Tuesday . . . The morning mail brings the sales record to Milwaukee. A girl codes the order into machine language, and sends it to Data Processing, where it is keypunched onto a standard IBM card, Figure 2. This transaction card is fed into RAMAC to update all memory records for that particular motor starter: the number remaining in Philadelphia warehouse, the total number shipped this week and this month by Philadelphia, the total number shipped this month from Mil-

SALE ENTERS COMPUTER

FIG. 2. Girls in central Data Processing Dept. keypunch an average of 1,200 customer orders daily into transaction cards for entry into RAMAC.

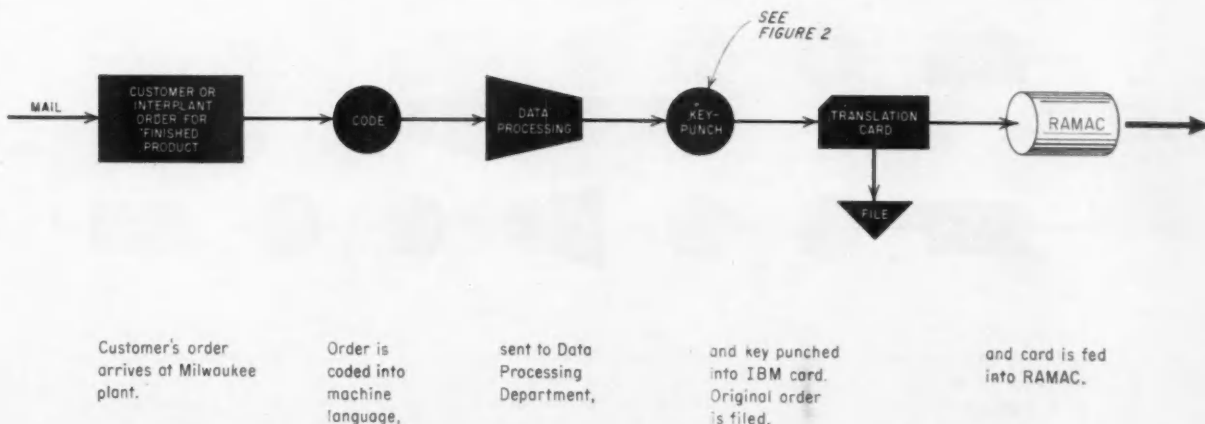


FIG. 1. Simplified flow chart (continued on following pages) shows progress of single order through inventory control and production planning systems. Step by step progress through flow diagram is detailed in text.

waukee and all warehouses, and the total number remaining in Milwaukee stock. RAMAC then compares the total number remaining in Milwaukee with the present "order point"—or point at which a production order for motor starters will be issued.

The original order for 1,000 breaks the Milwaukee inventory order point. RAMAC thus kicks out a production order request card "suggesting" that Milwaukee make more starters.

Wednesday A production planner gets production order request card, compares it with manually-kept stock record for that item, Figure 3. The stock record shows past sales records, ordering factors, standard quantity order amounts, and average monthly requirements. On the basis of these figures, the planner decides to issue a production order—adding human approval to a computer decision.

Thursday The planner sends approved production order request card back to Data Processing. A header card is keypunched showing number of motor starters to be manufactured. The header card is fed into RAMAC, Figure 4, along with two IBM card decks: a bill of material deck, and a factory routing deck. RAMAC updates all on-hand parts records, the on-order records for finished motor starters, prints out a bill of material list, punches out labor tickets for payroll,

and punches out a work order giving authority to manufacture.

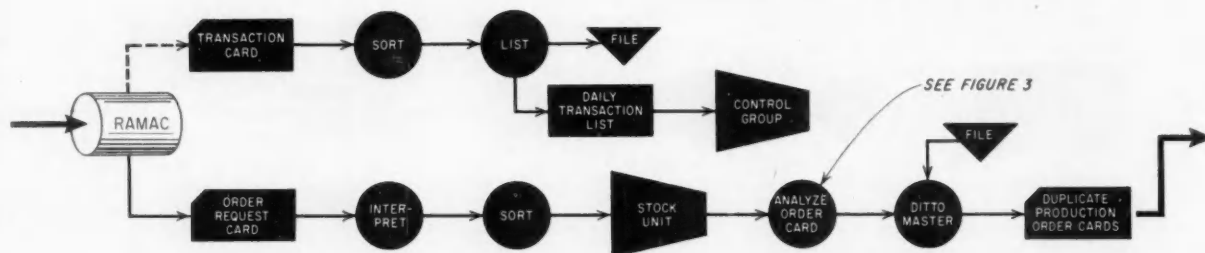
The quantity of each component part in the starter is automatically retrieved from the RAMAC file. The header card requests 2,000 starters, and the quantity required for each component part to make 2,000 starters is printed on the card for each part. The result is a complete bill of materials card deck for 2,000 starters.

The same kind of information is stored for each component part as is kept for finished parts: the quantity on hand, quantity on order, average monthly requirements, manufacturing lead time, order point, etc. When the header card is fed into RAMAC, all quantity information is updated.

After compiling a bill of material deck, Data Processing sends the deck to the Material Control Dept. along with deck of work and assembly order cards which had been compiled previously from engineering drawings and route sheets. The work and assembly order cards indicate what shop equipment is required to make each component part, the order of each manufacturing operation, and the order in which the product is assembled. Lead times are indicated to enable planners to set production starting dates which will bring all parts together at the right time for final assembly. One batch of parts does not have to be stored while another batch is being manufactured, and

PLANNER SANCTIONS MAKE ORDER

FIG. 3. Production planner compares computer order for new production with manually maintained production and stock records as management check on computer.



RAMAC sees that customer's order breaks order point, makes order request card

which goes to Stock Unit to be analyzed by Production Planner. Decision is made to

produce standard quantity of parts. Ditto master is pulled and set of production order cards duplicated.

shop employees and machines are not idle because they have to wait for a batch of parts to be completed in another operation.

Friday . . . In a weekly planning session, management takes over with human decisions, Figure 5, after RAMAC has completed routine work. Shop load reports—also printed out by the computer—indicate present and planned load on each shop machine and on work force. With the aid of work and assembly order cards, plus these printouts, management can fit production of 2,000 motor starters into the present flow of materials without overloading either machines or employees.

Actually, management is planning production several weeks ahead—the order of 1,000 starters should be anticipated by prior planning. Square-D is able to do this because available sales information is never more than one week old, and can be fresh the same day.

Thus, four days after a Baltimore customer places his order, the Milwaukee plant is ready to manufacture enough items to replenish the Philadelphia warehouse and Milwaukee's own stock. The same job used to take six to eight weeks. Actual replenishment might have been made within one week if the factory had enough stock on hand to meet this unusually large order. In fact, a warehouse frequently receives replenishment stock before an order can be shipped.

When the bill of material deck was compiled, two statistical changes were made in the computer memory: 2,000 starters were added to the Milwaukee on-order balance, and the quantity for each component part was extended by 2,000 assemblies. After the 2,000 starters are manufactured, another card is keypunched and fed into RAMAC which transfers all the above amounts from on-order to on-hand records.

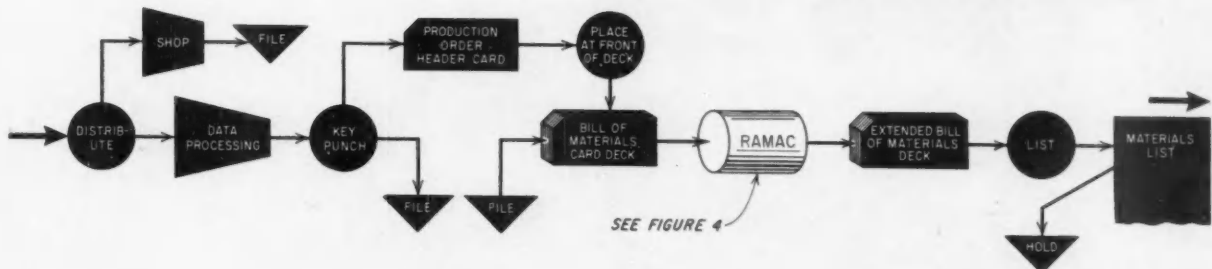
Every week RAMAC prints out a warehouse replenishment shipping list. To do this, RAMAC checks every finished product for the quantity due each warehouse—the on-order balance. When a warehouse is located which needs more stock, and there are sufficient items on hand in Milwaukee stock, RAMAC prints out the warehouse location, product description, and quantity due.

(If the quantity needed by a warehouse is less than one-tenth of the minimum allowable stock on hand, no replenishment is made. The amount needed is added to the quantity already due the warehouse from other orders to prevent uneconomical shipping. Thus, small replenishment orders are lumped into one larger order.)

Two copies of the warehouse replenishment printout are sent to the shipping department. As the stock man fills the order, he checks off directly on the first copy, Figure 6. When the order is packed and ready for shipment, the packer checks

RAMAC ORDERS ALL PARTS

FIG. 4. IBM 305 RAMAC computer maintains all stock records at factory and warehouses. At this point in order handling, RAMAC produces a complete bill of materials breakdown in the form of a deck of punched cards for all parts to be manufactured to fill order and return stocks to desired levels.



One production order card goes to the shop, and one goes to Data Processing,

is key punched with quantity of product to be made, and becomes header card

for bill of materials deck, which is extended by RAMAC to exact number of all component parts. All

on-order records are updated, and a complete bill of materials list is printed.

off on the second copy. In this way, the actual printout is utilized as a shipping and packing form in the warehouse.

This example described the process for just one customer order. Two daily mail deliveries in Milwaukee bring an average of 1,200 customer orders, and each one is put through the same process in random batches. Feeding customer orders into RAMAC is a continuing process done just as fast as orders come in. RAMAC looks for broken order points on each order, and records how many items each warehouse has on hand, etc. The net result is an inventory and production system with the benefits of perpetual inventory on a daily basis.

Utilizing computer speed, Square-D's Industrial Controller Division keeps production only one week behind actual sales; eventually, Square-D hopes to make sales and production curves match exactly by using larger computers with faster random-access memories.

Warehouse replenishment on this basis has allowed Square-D to level off inventories at lower quantities. Because Milwaukee can send new stock every week, inventories have been reduced as much as 30 percent compared to levels held before computers arrived. Inventories also remain fairly constant, at or close to desired levels, because production can be geared directly to a customer's

order. The company said it now saves many thousands of dollars yearly in warehousing costs alone.

The computers do other jobs

In addition to the daily job of controlling production and inventory, several equally important jobs are done monthly and yearly. In each case, the computers have produced excellent results, according to the company.

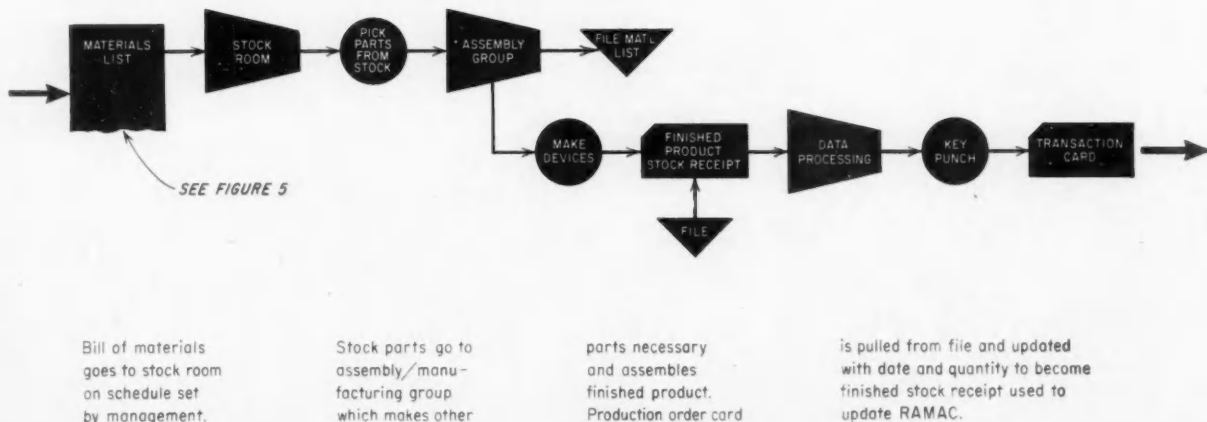
Square-D puts many new products on the market every year, and many of these make older designs obsolete. Prior to the computers, warehouse managers were unable to prepare adequately for new products; often they were caught at the end of the year with too many obsolete items. Now, tapes can be run months in advance showing what each warehouse has in stock. With this information, production and inventories can be modified to insure the least possible number of obsolete products still on the shelf at a year's end—giving space to the greatest number of new products.

Each year, Square-D evaluates its standard cost system for all parts and products. This detailed job involves production rates, purchasing, administrative costs, warehousing costs, labor costs, taxes, depreciation, profits, and many other kinds of information. The last time it was done before computers arrived, the job took nine months and



MANAGEMENT SCHEDULES SHOP LOAD

FIG. 5. Weekly management session to check RAMAC shop load reports against work and assembly order cards anticipates shop load for current orders to make shop space and labor available as needed.



A yearly inventory is taken of all 30,000 stock items; by doing this, all excess inventory is located and can be cleaned out. The job used to be done in three months by 20 people. RAMAC and one man do a better job in six hours, just by telling the machine to print out a list of all items on hand and the quantities in every warehouse. In addition, RAMAC can compare these figures with sales forecasts to determine where changes should be made.

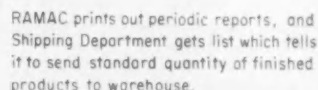
The Industrial Controller Div. has placed orders for two new IBM 1401 machines to replace the older 305s. The 1401s will handle present computer activity and have time left over for several new programs.

operations can be programmed into the 1401 because it has a larger memory. The computer will decide whether to replenish warehouse stock, start new production, order more parts, and make other decisions now made manually. The 1401 will operate by itself on all routine cases, and flag out only exceptions to the rules for human decision.

Variable order points is one of the projects Square-D is developing. Order points—the least number of items Milwaukee can have on hand before more must be ordered—are now set on the basis of knowledge, market research, experience, rules of thumb, and past sales records. The company is studying factors for an exponential smoothing equation which accounts for this information and which can be programmed into the computer. Result will be a further trimming of inventories, plus increased warehouse stability.

Many inventory items are purchased from vendors. When a vendor item order is broken, a purchase order must be written by hand. Square-D plans to make purchase order writing part of the 1401's job: when these order points are broken, the computer will print out a purchase order complete with quantity, part description, the vendor's name and address, and price extended by number of units. The only human touch will be a signature on the form before it goes out the door.

FIG. 6. Stockman checks items off directly on first copy of computer-printed order to replenish warehouse from factory stock.



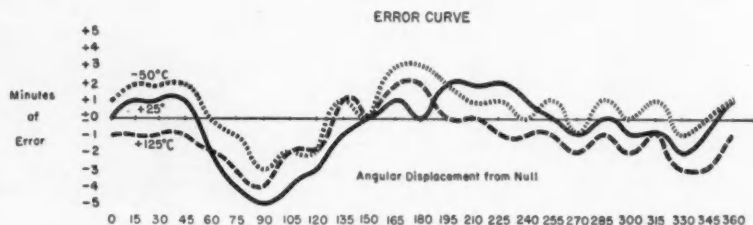


This SYNCHRO offers temperature stability plus lightness

This Size 8 Daystrom Transicoil synchro provides temperature stability without increasing weight.

The encapsulated stator windings permit these units to be operated under severe environmental conditions. And, of greatest importance, in random sampling of Daystrom Transicoil Size 8 synchros, error shift from room temperature has not exceeded 2 minutes over the entire temperature range of -55°C to $+125^{\circ}\text{C}$.

Daystrom Transicoil Size 8 "temperature stable" units are



available as transmitters, differentials, control transformers and resolvers. Standard accuracy is ± 7 minutes, but 5-minute units are also available on special order.

Data sheets and prints on the "temperature stable" Size 8 synchro are available on request. And remember, too, Daystrom

Transicoil makes a complete line of precision rotating components.

Foreign: Daystrom International Division, 100 Empire St., Newark 12, New Jersey. *In Canada:* Daystrom Ltd., 840 Caledonia Road, Toronto 19, Ontario. *Mid-West:* Daystrom Incorporated, 905 W. Hillgrove Avenue, La Grange, Illinois.

DAYSTROM, INCORPORATED
TRANSICOIL DIVISION

WORCESTER • MONTGOMERY COUNTY • PENNSYLVANIA

Digital Inspector Grades Components

IDEAS AT WORK

KLAUS H. JAENSCH
Stromberg-Carlson Co.

This sorter (patent pending) automatically separates into 10 tolerance grades resistors, capacitors, inductors, ferrite cores, and other components whose properties can be measured by a digital voltmeter or frequency counter. The readout of a single decimal counting unit of the digital meter characterizes the 10 grades. The step between grades is set by the range of indication chosen. For example, with a nominal value between 94 and 95 and a range of from 90 to 99 the last digit determines one of 10 possible grades in steps of nearly 1 percent. For 2 percent steps the ranges 40 to 49 or 50 to 59 would be used. Since most digital instruments have plus or minus 1 count accuracy, the least significant digit should be neglected and the next to last counting unit used for sorting.

The four-line binary coded decimal output of the digital counting unit controls the sorting mechanism sketched in Figure 1. Each line operates one or more rail switching flaps through a thyatron actuated solenoid.

The component drops through the forked chutes and is guided into one of the bins according to the positions of the various flaps. Potentials on the four lines of the preceding counting unit are checked by a decoder which operates the top solenoid in Figure 1 only if the right code is present. If not, the component is rejected.

Automatic operation requires the additional circuits and mechanisms shown in the block diagram, Figure 2. As soon as a component is present in the test jig the presence detector initiates the read cycle. A contact mechanism could be used here, but for greater reliability the detector is an L-C oscillator designed not to oscillate when the wire lead of a component is in the field of the coil. When oscillation stops, the make-contact amplifier and solenoid connect the component to a test circuit which varies with the type of component sorted. At this time, the start-counter circuit resets the digital meter to zero by briefly interrupting the negative potential it has kept on the "inhibit reset" terminals to hold the previous display. The meter now reads the output of the test circuit. Most digital instruments also have

"count completed" signal output terminals. The potential available here is positive during the short time the instrument is counting and negative from count completion until the next reset. The change from positive to negative switches the bistable make-contact circuit to remove the contacts from the component. The same signal trips the monostable probe-release amplifier and solenoid which retracts a mechanical stop and drops the component into the chutes.

When sorting resistors, the test circuit can be a constant current generator adjusted to produce the desired voltage drop across a resistor of nominal value. The drop is then read with a digital voltmeter. An alternate circuit employs a stable voltage source and a precision series resistor. By choosing proper values of voltage and resistance, the step between grades can be made an even value. The same arrangements can be used to sort capacitors if the applied voltage is stabilized sinusoidal ac and the digital instrument will measure ac voltages.

Inductors to be sorted are connected as frequency determining components of an L-C oscillator. Since C is fixed the oscillation frequency is

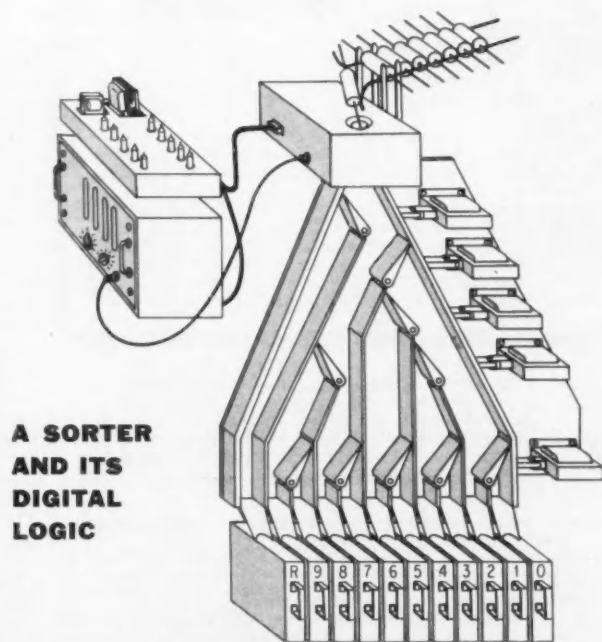


FIG. 1. Counter operated flaps channel components into one of 11 bins.

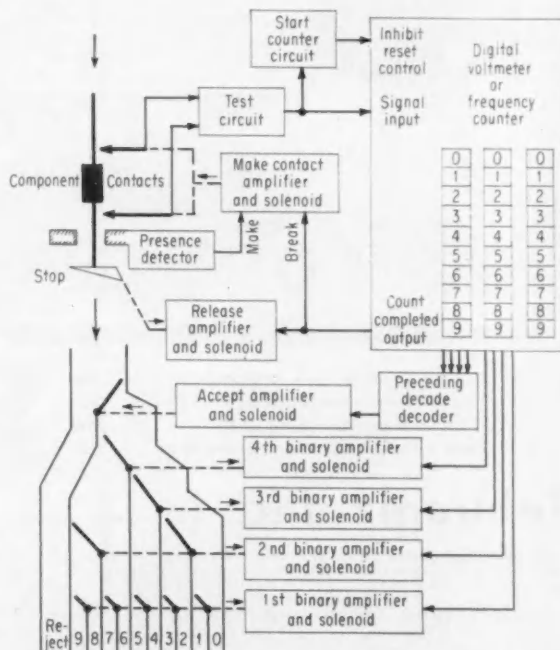
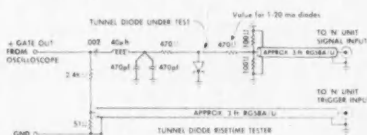


FIG. 2. Control circuits use connections normally available on digital instruments.

**Typical waveform of
gallium arsenide tunnel diode.**

Other pulse-sampling applications requiring *only* the oscilloscope and Type N Unit include those wherein a repetitive signal has a $\frac{1}{2}$ to 2 volt, 45 to 200 nanosecond pre-trigger, or a repetition rate from 10 to 50 megacycles.



Calibrated vertical display
in ma/cm of collector current

Typical display of diode reverse-recovery characteristics—with forward current at 20 ma and reverse current at 0.1 ma.

*Overall risetime depends partially upon your Tektronix oscilloscope—typically the same as listed with the Type R Unit.

A Tektronix Type S Diode-Recovery Unit* enables you to display and measure both forward and reverse switching characteristics of semiconductor diodes. You can determine effective lifetimes to 2 nanoseconds, stored charge to 10 picocoulombs, junction capacitance to 2 picofarads, and base resistance to 0.25 ohm. Parameters measured from the curves can be used to predict the behavior of many diodes in many circuits, as well as compare diodes for performance in a particular circuit.

A Tektronic Type Z Differential-Comparator Unit provides an equivalent vertical scale length up to ± 2000 centimeters at 50 mv/cm, enabling you to accurately resolve incremental voltage or current changes in semiconductor circuits.

With Zener diodes, for example, you can display Zener voltage as a function of current or temperature. You can clearly show several important Zener diode instabilities, including white noise and microplasmas (multiple-breakdown phenomena at low junction currents).

The waveform illustrates instabilities of a 1/4 watt Zener diode. With Zener voltage of 106 v at 0.75 ma and Zener impedance (calculated) of 170 Ω over the current range of 0.75 to 1.34 ma, the microplasmas shown indicate that this Zener diode should not be operated below 0.24 ma.

Type S Diode-Recovery Unit	\$250
Type R Transistor-Risetime Unit	300
Type N Pulse-Sampling Unit	600
Type Z Differential-Comparator Unit	525

(prices f.o.b. factory)



For a demonstration of any of these 4 plug-in units in your own work with semiconductor devices, call your Tektronix Field Engineer. Ask him for the free 32-page booklet—which lists complete specifications and performance details of all 16 "letter-series" plug-ins for Tektronix Oscilloscopes.

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TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics, Portland, Oregon; Seattle, Washington. Tektronix is represented in twenty overseas countries by qualified engineering organizations. In Europe please write Tektronix Inc., Victoria Ave., St. Sampsons, Guernsey C.I., for the address of the Tektronix Representative in your country.

inversely proportional to the square root of L . For small deviations, a plus p percent variation in L is equivalent to a minus $p/2$ percent change in frequency. Frequency is measured with a digital frequency meter whose output operates the sorting mechanism. To use the meter for straight frequency measurement, the oscillation frequency has to be a decimal multiple of the counter range chosen. In some cases this may be very different from the frequency at which the coils should be checked. Then instead of using the standard 1-sec clock pulses normally applied to the counter's

gate, the counter can be used to measure the ratio between the frequency of oscillation and a stable, standard frequency applied to the gate from an external generator.

Ferrite cores are sorted in a similar manner except that an air-wound coil is permanently connected in the resonant circuit of the oscillator. The cores are inserted into this coil and determine the final inductance value. The make-contact amplifier and solenoid are not required, and, if the test circuit is designed not to oscillate with the plain air coil, neither is the presence detector.

Sorting allows components with poor manufacturing tolerance to be assembled to meet rigid specifications. Ferrite cores with a wide tolerance of permeability can be used for making chokes with a ten times narrower inductance tolerance if they are sorted and a different number of turns of wire is applied to each grade. Inductors and capacitors for filters can be graded, and inductors of grade 0 assembled with capacitors of grade 9, and so on. In this way, the tolerance of the combination is kept ten times narrower than if components were combined indiscriminately.

Road Load Computer Brings Highway to Lab

DON WINSTON
McGraw-Hill News

An electronic analog computer, Figure 1, has enabled a major West Coast oil company to pull at least 80 percent of its former road testing into the laboratory. Developed by Donner Scientific Co. (now a part of Systron-Donner), the computer operates through a controller and power amplifier to regulate the torque applied by dynamometer rollers to the rear wheels of a test vehicle. Almost any highway conditions can be simulated.

In conventional road testing, trained drivers take the cars over a standard course at preselected speeds and accelerations. Recorders continuously measure engine performance while the driver tests different blends of gasoline by switching fuel lines connected to several gas cans. Later analysis of the tapes gives a profile of gasoline performance in the vehicle. Considerable time is wasted in driving to the course and returning, and wind and temperature variations affect results.

The job of the road load computer is to vary the current to the dynamometer field windings to accurately reflect the torque that would be encountered by the rear wheels of the car in an actual road test. Built into the system, Figure 2, is a feedback loop which compares measured torque with the computed value. Speed of the rollers is measured with a tachometer whose readings are fed to the computer. Acceleration is then computed via a time derivative. Net velocity with respect to wind affects the vehicle's wind resistance, and this must be taken into account in deriving the torque signal.

Two sets of parameters must be set into the computer by the operator.

One set contains the known characteristics of the car and includes the rolling resistance of the front wheels, the air resistance factor (effective area times an aerodynamic coefficient), and the weight of the vehicle. These constants are maintained throughout the test. The second set of parameters involves the variables of grade and wind direction. Uphill and downhill grades of up to 30 percent, and headwinds and tailwinds up to 100 mph can be simulated. From these fac-

tors the computer derives an appropriate torque signal. The operator can dial a 5 percent grade and a 30 mph headwind, and the driver riding the rollers will feel the corresponding pressure on his car's rear wheels. When the operator dials a sharp down-grade, the driver will feel the need to step on the brakes.

To prevent unrealistic engine overheating, a wind generator produces air circulation consistent with the simulated speed of the vehicle.



FIG. 1. The computer operator sets up road conditions.

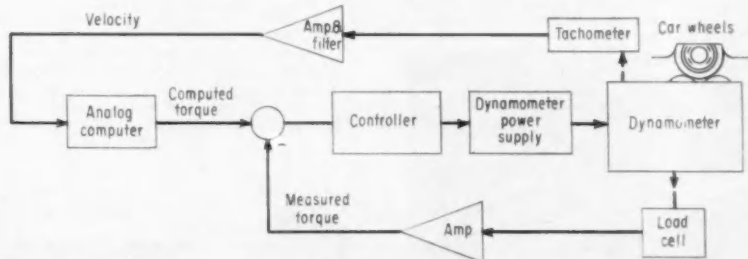
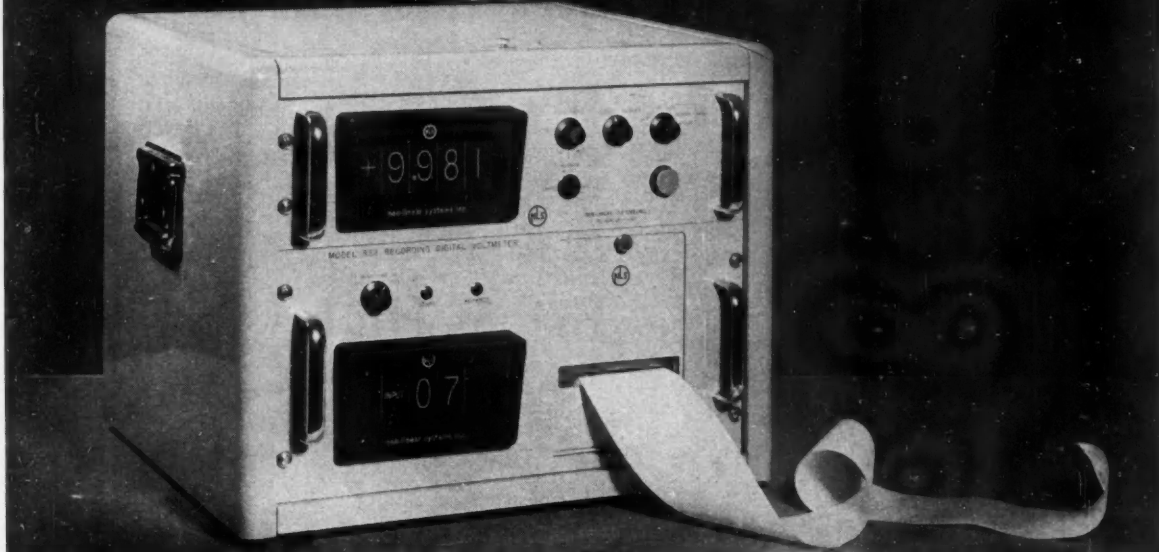
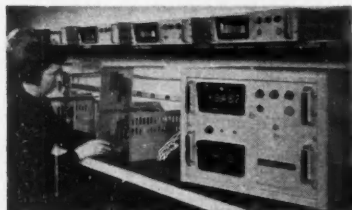


FIG. 2. Test system compares measured and computed torques.

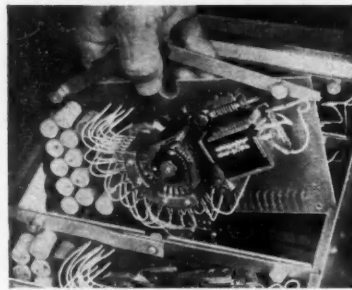
High Precision Data Logger for \$3,600



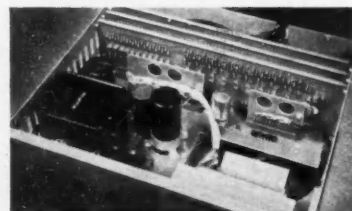
The RS2 Recording Digital Voltmeter — now in volume production at Non-Linear Systems, Inc. — scans up to 20 double-pole input channels . . . measures DC voltage from ± 0.001 to ± 999.9 with $\pm 0.01\%$ accuracy . . . and records input channel number and the 4-digit voltage measurement. Uses include research and development, quality control, environmental and reliability testing.



Volume production and simplified controls of the RS2 account for its low cost — half to a third less than custom-built units.



Plug-in stepping switches in the digital volt-meter section of the RS2 permit replacement of all switches and decade resistors in minutes instead of days.



Note the compact, plug-in modular design of the scanner-printer section of the RS2.

NLS Reports on Low-Cost, Standard Data Logger

A low-cost automatic data logger built as an integrated scanning, measuring and printing system — the RS2 Recording Digital Voltmeter — is now in volume production at Non-Linear Systems, Inc.

This economy-priced NLS logger is designed for applications requiring high accuracy and low cost without need for the higher speed and greater input capacity of higher cost NLS systems. Simplified controls offer several automatic and manual modes of operation to meet the needs of a great number of applications. While utilizing many circuits field-tested for six years in thousands of NLS digital voltmeters, the RS2 has undergone extensive testing as a standard, complete system. It is delivered ready to use, without need for additional engineering or complex interconnections.

Call your NLS regional office or representative for a demonstration, or write NLS.

RS2 BRIEF SPECIFICATIONS

Visual Indication: 4-digit voltage reading with correct polarity and range. 2 digits for input channel identification.

Range-Polarity Indication: automatic

Functions: scanning up to 20-double-pole channels; measuring DC voltage from ± 0.001 to ± 999.9 in ranges of $\pm 9.999/99.99/999.9$; printing channel number, 4-digit reading, polarity and decimal point placement.

Accuracy: $\pm 0.01\%$ of full scale on each range.

Speed: 2 seconds average for each data point scanned, measured and recorded.

Scanner Operation Modes: AUTO CYCLE — sys-

tem continually repeats automatic scanning cycle from channel 00 to 19. ONE CYCLE — system automatically stops after scanning channel 19. PRINT — one input is measured without advancing scanner. Scanner may be manually advanced one channel at a time by depressing front panel ADVANCE button.

AC Voltage: Use NLS AC/DC Converter.

Low-Level DC: Use NLS Model 140 Preamplifier.

Input Impedance: 10 megs on all ranges.

Size: 14" high, 15 1/4" deep for 19" rack.

Delivery: From stock, 30 days, maximum, should stocks become depleted.



Originator of the Digital Voltmeter

non-linear systems, inc.

DEL MAR, CALIFORNIA

Analyzer Counts and Times Amplitude Excursions

P. R. THOMAS, General Electric Co.

Manual reduction of test data is often highly repetitive and can waste a great deal of engineering time. The analyzer described here takes electrical analog data from a magnetic tape recorder and automatically turns out digital information in a form that is directly usable in statistical analysis. It will count the number of times a variable exceeds a given reference, or total the time that the variable exceeds the reference. To do a probability distribution analysis it is only necessary to run several counts using various reference levels, after which subtraction will provide data that can be plotted as a probability curve. An amplitude slicer used with the rest of the analyzer will eliminate the need for subtraction.

Figure 1A is a functional diagram of the analyzer when operating in the counting mode. An electrical analog of the variable is fed to a linear amplifier/gate combination. When the gate is opened on external command, the amplified signal goes to a counter, which has been preset for some number of counts, and to an amplitude comparator. Positive or negative excursions or both can be counted on the preset counter. At the same time, these excursions are compared with a self-contained 0-10-volt reference in a comparator which produces an output only when the input exceeds the reference. These output pulses are counted by the events-per-unit-time (EPUT) meter. After the preset total of excursions has been registered

on the first counter, the input gate is closed. The preset counter then shows the total number of excursions from zero which were seen by the analyzer, and the EPUT meter shows how many of these events exceeded the reference level. Figure 1B shows a typical random input and the portions of it that would be counted at two different reference levels. Some ambiguity is possible in this mode.

Figure 2A shows how the equipment is set up for timing. The interconnections are somewhat different, and two gates have been added. Here the input signal, after passing through the amplifier and gate, is fed to the comparator only. When the signal exceeds the reference, gate 2 is opened allowing the EPUT meter to count its own clock pulses. When the signal is below reference level, the EPUT meter does not count. Gate 3, synchronized with the input gate, allows the preset counter to count all clock pulses and register total analysis time. When the preset number of counts (time) is reached, gate 1 closes, cutting off the input. The EPUT meter then registers the amount of time the input was above the reference. Figure 2B shows the same random input as Figure 1B. Here no ambiguity exists.

The amplitude comparator of Figure 2A can be replaced with a slicer (dual comparator) which provides an output only when the input variable is between the limits A and $A + \Delta A$. The EPUT meter will then count the

time the input signal spends between levels A and $A + \Delta A$.

The analyzer was put together from stock components and instruments, most of which can do double duty in other applications. From top to bottom in Figure 3 are a Philbrick A-100 B power supply; a Hupp (Erie Instrumentation) Model 400 counter-timer; an Erie Instrumentation Model 320-D preset counter; an SKL Model 302 dual variable electronic filter for signal conditioning; the basic analyzer, lab-constructed using stock plug-in amplifiers, gates, and flip-flop; and a locally constructed operational amplifier manifold for signal preamplification and conditioning if desired. If the counter, gates, and flip-flops are available, such a device could be constructed temporarily on any general purpose analog computer.

One use is the determination of duty cycles (percent of time above indicated speed or acceleration) of motors and vehicles.

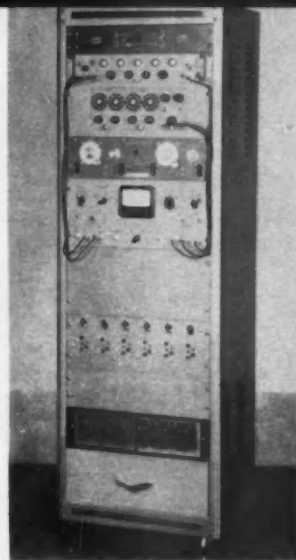


FIG. 3. The analyzer is assembled from standard components.

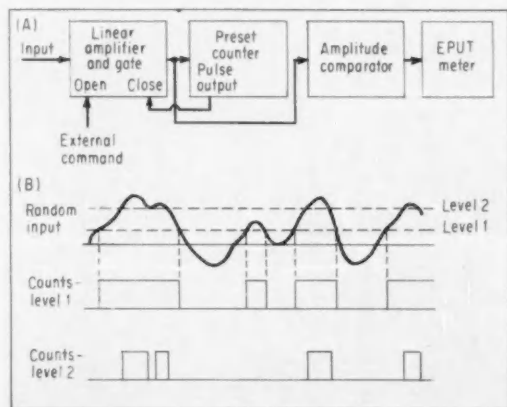


FIG. 1. Signal excursions which exceed a reference are counted.

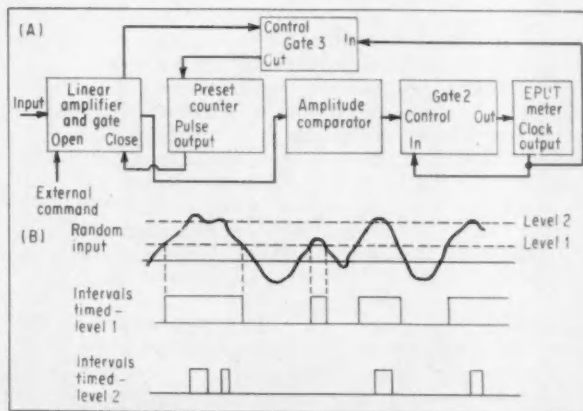
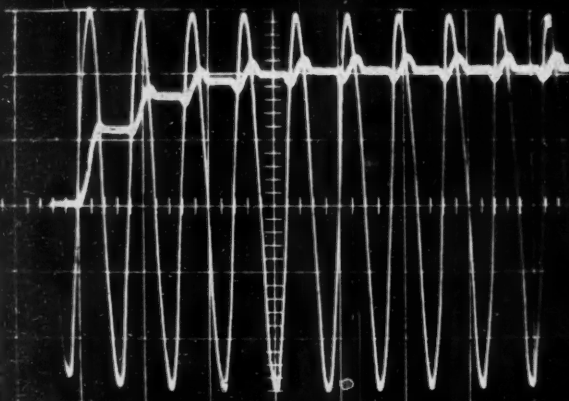


FIG. 2. With two more gates, the time the signal exceeds the reference can be totaled.

AC MEASUREMENT

FAST AND PRECISE

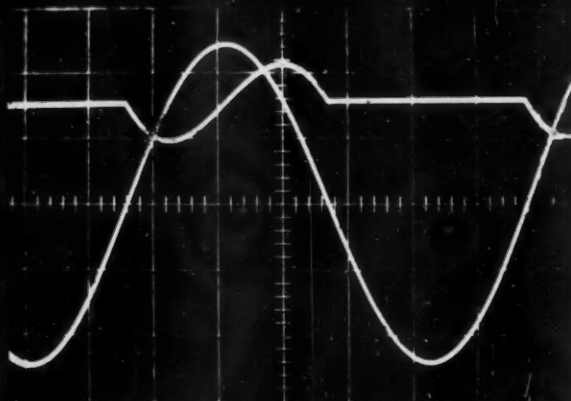


FAST ACQUISITION

Superimposed input and output waveforms show the fast response time of Adage's Type ACS1 AC Averager. Short filter time constant allows the steady state value to be achieved quickly.

PRECISE MEASUREMENT

The ripple present in the output waveform does not interfere with the precision of the measurement. Timing circuitry insures that the voltage measured is that value present during the interval when the output is ripple free.



Modern instrumentation systems demand equipment to make fast, precise measurements of AC signal waveforms. This required combination of speed and accuracy is beyond the capability of conventional techniques. For example, a conventional diode-capacitor AC/DC converter requires at least three seconds settling time to make 60 cps measurements. When many different signal sources must be scanned and measured successively, this slow response time limits seriously the overall system speed.

Slow response time is also a disadvantage in AC carrier systems. The transformer-driven diode bridge demodulators conventionally used as phase-sensitive AC measurement instrumentation for these systems have inherent limitations in both speed and accuracy. They tend to compromise the performance of instrumentation systems using them.

There has been, then, a clear need for innovation in the field of AC measurement. Responding to this need, Adage has developed several new AC measurement techniques. Among these is the fast-averaging technique illustrated in the accompanying waveform photographs. This technique offers substantially improved performance both for self-synchronous and phase-sensitive measurements. Response time, for example, is improved by more than a factor of ten to one. Used in conjunction with precision voltage to digital converters, modules implementing these new measurement methods have been successfully applied in many industrial and military instrumentation systems. A typical solid-state, AC Signal Conditioner is comprised of three 5" x 8" epoxy fibreglass circuit modules, easily incorporated in any of the Adage VOLDI-CON® voltage to digital converters.

Applications notes and technical data describing in detail Adage's AC instrumentation capability is available upon request.

Adage
INC

292 MAIN ST., CAMBRIDGE 42
MASSACHUSETTS

West Coast Facility: 1145 East Ash Avenue, Fullerton, California

NOR Gates Control Conveyors

W. J. KORCHAK
General Motors Corp.

A static control system has been applied to two automatic side frame loaders at the Buick-Oldsmobile-Pontiac Div. assembly plant in Arlington, Tex. The system, called Norpak by its manufacturer, Square D Co., uses NOR gates almost exclusively. A NOR gate has an output if none of its inputs is present.

In the sequence shown in Figure 1, a charge conveyor loads automobile side frames onto an air motor driven, solenoid actuated bridge crane. This bridge crane automatically loads the frames onto a moving truck containing the underbody and rear compartment pan. The truck is carried on the main conveyor. There are two such charge conveyor and bridge crane setups, one for each side of the car; the systems are identical, though interconnected. They operate simultaneously, coming together at the truck to form a complete assembly, so synchronization is a prime factor for efficient operation.

When a side frame is completely on the bridge crane, it actuates a limit switch LS4, releasing the bridge crane latch, deenergizing the charge conveyor, and energizing the bridge crane motor, Figure 2. If LS4 is closed, it supplies a signal to NOR's 1, 11, and 16, giving them no output. Assuming that the power input is off to all the NOR's and that LS1 and LS2 are not closed, NOR 1 is off, turning NOR 2

on. This energizes the latching mechanism, releasing the crane.

Because NOR 16 is off, the charge conveyor stops. Now because NOR 11 is off and so long as OR A is off, NOR 12 is on, turning on the "in" motion motor. Figure 2 also shows that if the bridge crane reaches the

position of LS9 (almost to the conveyor loading point), the bridge crane "in" motor stops as LS9 closes if LS6 has not been closed. Closing LS9 turns NOR 19 off. This gives one off signal to NOR 20. As long as LS6 has not yet closed, giving the other off signal to NOR 20 (through

FIG. 1. The loading system's bridge crane moves transverse to the charge conveyor and the main conveyor, picking up frames from one and loading them on the other. A second bridge crane system is located on the other side of the main conveyor. Limit switches mentioned in the text and located here are described in the table below.

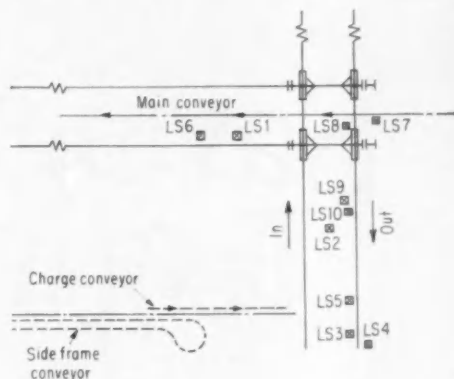
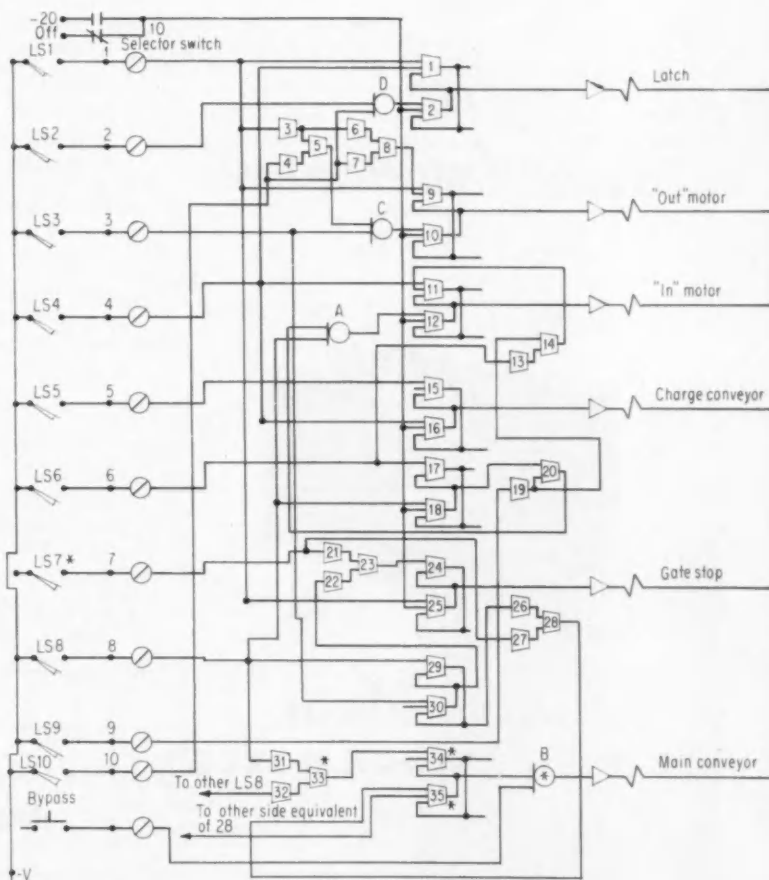


FIG. 2. Logic system for the frame loader indicates NOR elements as wedge shaped boxes, OR's as circles with a tangent line. All logic elements have counterparts in the second loader except starred ones which are common to both sides.

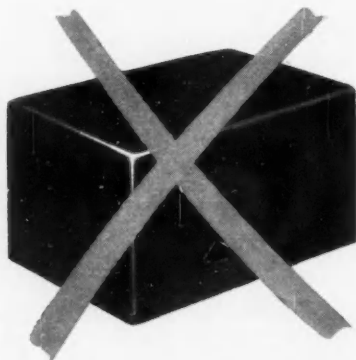


FUNCTIONS OF LIMIT SWITCHES

- LS1 Energizes latch mechanism
Deenergizes gate stop
Energizes "out" motor
- LS2 Deenergizes latch mechanism
- LS3 Deenergizes "out" motor
- LS4 Energizes latch mechanism
Energizes "in" motor
Deenergizes charge conveyor
- LS5 Energizes charge conveyor
- LS6 If LS6 is not made before LS9 (by bridge crane moving in), bridge crane stops
- LS7 Energizes gate stop. Stops main conveyor if both bridge cranes are not in position to load
- LS8 Deenergizes "in" motor
- LS9 See LS6
- LS10 If LS1 and LS10 are made simultaneously, "out" motor stops

ANOTHER Money Saving Feature

OF
Taylor Instruments



**ELIMINATION OF
EXTERNAL "BLACK BOXES"**

Today it is no longer necessary to clutter up your instrument panels with externally mounted "black boxes" for the operation of auxiliary devices such as process alarms, slidewires, etc. With Taylor TRANSCOPE® Recorders, both pneumatic and electronic, these functions can be built into the recorder. You save money . . . and labor . . . and panel space . . . and many headaches.

The secret is Servo Power. Powerful Servomatic motors built into the recorders not only give greater recording accuracy than ever before, but also supply the power necessary for precision operation of auxiliary mechanisms and computing devices. Power in the pneumatic servo is 150 greater than in the bellows-actuated type; in the electronic, it's 1,000 greater than galvanometer systems.

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* * *

When you buy TRANSCOPE instrumentation you're buying greater accuracy than ever before available—and you're insuring against future process control needs. Ask your Taylor Field Engineer for a demonstration, or write for **Bulletin 98286** (pneumatic) or **98335** (electronic). Taylor Instrument Companies, Rochester, New York, or Toronto, Ontario.

Taylor Instruments
MEAN ACCURACY FIRST

NOR's 17 and 18), NOR 20 is on, turning on OR A, and deenergizing the bridge crane "in" motor. However if LS6 has closed, NOR's 13 and 20 are off, so the motor remains running. This interlock arrangement assures that the bridge crane will not reach its unload point before the previous truck (sensed by LS6) is out of the way. Also shown by the logic diagram of Figure 2, LS8 stops the bridge crane when it is in position for unloading.

At the unload point the control system (via LS2) sets the latching mechanism (by deenergizing it) to hold the bridge crane in place. Simultaneously, the bridge crane motor solenoid is deenergized (via LS8 through OR A). A gate stop holds the side frame away from the truck for

clearance, Figure 3. When the truck is in the right spot, LS7 releases the gate stop and the side frames (on each side) swing into position and lock in place. The LS8's on both sides also stop the main line conveyor if either bridge crane is not in position.

When the side frame has cleared the bridge crane, LS1 deenergizes the gate stop, releases the bridge crane latch, and energizes the "out" motor so the crane can pick up another load.

In justifying the cost of this static control system over conventional relays, GM used this rule of thumb: if in a relay control circuit of medium complexity a number of loads are each controlled by five or more interlocking relay contacts, then the cost of the static system is close to that of a conventional control system.

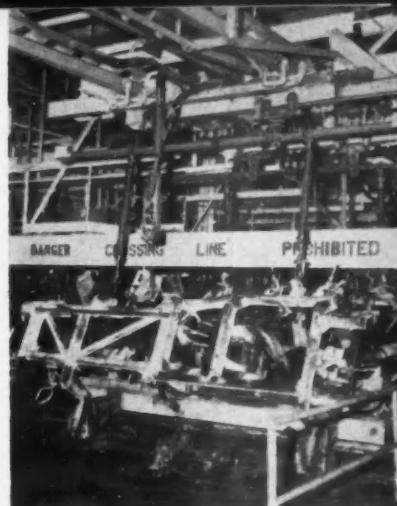


FIG. 3. Gate stops hold side frame away from truck until two frames and truck are aligned.

Water Tank Rids Ships of Roll

A new system for damping out the roll of a ship at sea consists of little more than a specially shaped tank of water. Unlike more elaborate fin stabilizers (see CTE, March '59, p. 99, for one example), its action is the same whether the ship is underway or hove to. Designed by John J. McMullen Associates, Inc., the system contains one or more pairs of tanks with connecting flumes, Figure 1, installed athwartships. The tanks are filled to a predetermined level with water or other liquid. The flume nozzles, i.e., the rounded vertical corners where the flume and tanks are joined, are designed so that the free surface moment of the partially filled tanks lags the corresponding moment for static inclination of the ship by 90 deg. Water flowing into the tank on the side of the ship trying to rise dampens the roll.

Flume stabilization tanks can be made part of the hull structure in new vessels, and existing bulkheads can be utilized when the system is added to an operating ship. These stabilizers are now in use in the liner *Matsonia*, the oceanographic ship *Vema*, and several U.S. Navy missile tracking ships. Figure 2 shows a 1/108 scale model of the *Matsonia* rolling in regular beam swells (1.7 deg surface wave slope) at its natural roll period (19 sec). The maximum roll is only 3 deg. If the water in the flume is replaced by a like weight of solid ballast the roll is 14 deg under the same wave conditions. The location of the tanks is not particularly important. In the *Matsonia*, a 7½ x 18 x 70 ft stabilizer was built into part of an

unused cargo hold halfway between the aft stack and the stern at the water line. In the *Vema* there was no space available below decks, so the tanks were located atop the pilot house. The cost of installing the stabilizer on the *Matsonia* was under \$200,000. Matson Line officials said it would have cost more than \$1,000,000 to install fin stabilizers, whose effectiveness varies with the speed of the ship.

In passenger ships the weight of water in the flume is only a small fraction of a percent of the ship's total displacement. If desired, a liquid cargo or reserve fuel can be used in the flume instead of water. The stabilizer cuts operating costs because the

reduction of roll and absence of a bilge keel (not required) reduces hull and wave resistance by about 7 percent. There is much less crockery and glassware breakage, an item which can run to \$50,000 a year in a ship the size of the *Matsonia*. The only added expense is that a lot more passengers show up for breakfast.

A less effective passive stabilizer, the Frahm U-tube system, was installed on some 40 ships around the turn of the century. Two pipes, one for water and one with a valve for air, connected tanks on either side of the vessel. This system had a tendency to destabilize the ship if too lightly damped, and the air venting between the tanks was noisy.

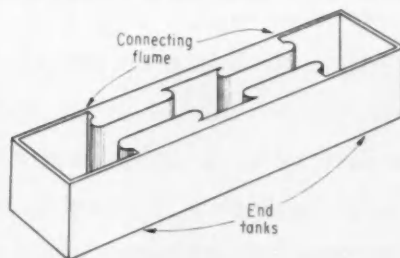
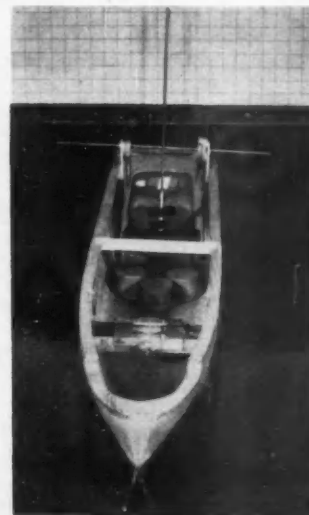
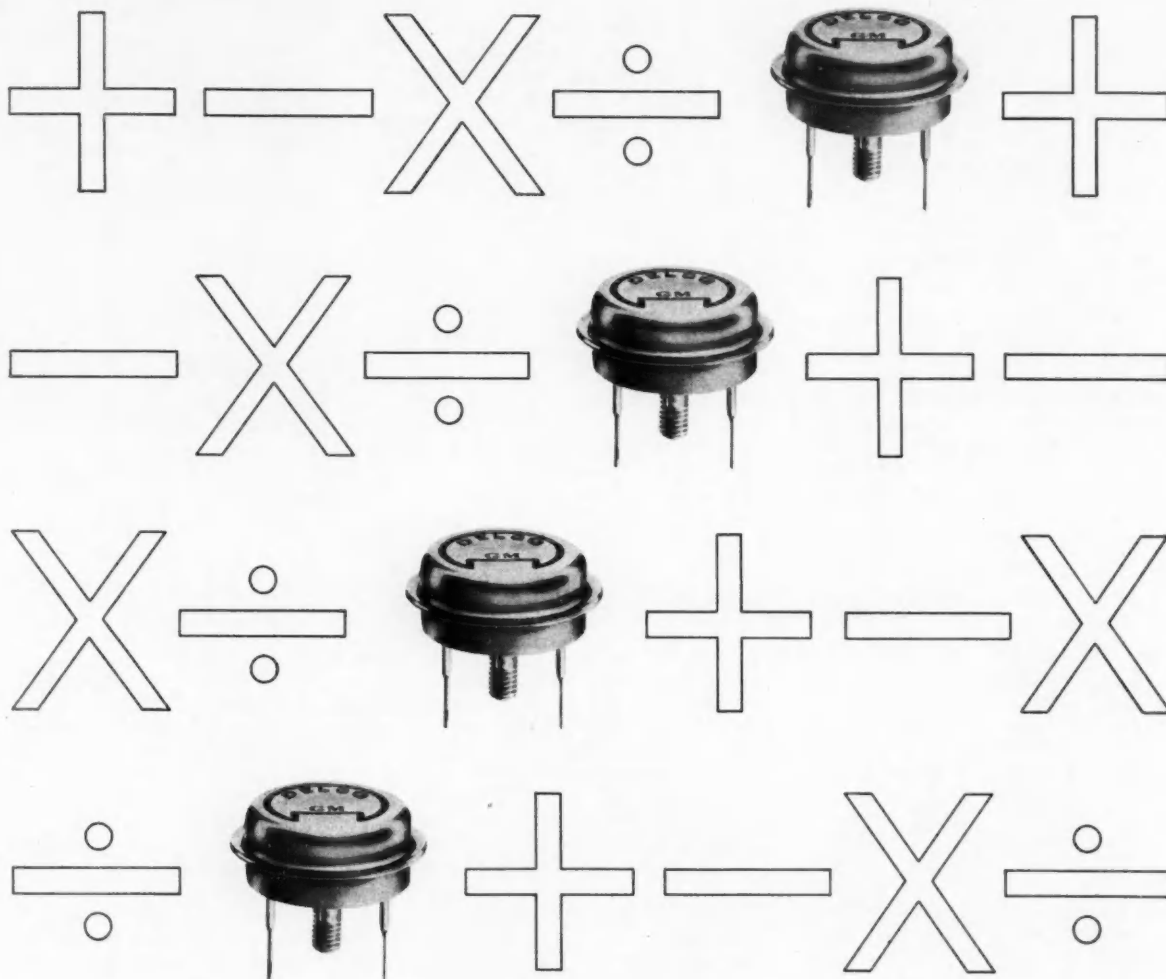


FIG. 1. Typical flume stabilizer. Two or more may be used.

FIG. 2. Model of the S.S. *Matsonia* rolling in artificial waves. Flume system is in the foreground.



(Photo by Davidson Laboratory, Stevens Inst. of Tech.)



DELCO POWER TRANSISTORS PROVED IN COMPUTERS by IBM, UNIVAC®, BURROUGHS, NATIONAL CASH REGISTER

Since Delco Radio produced its first power transistors over five years ago, no transistors have undergone a more intensive testing program to assure reliability—which accounts for their popular acceptance in hundreds of industrial and military uses. Before leaving our laboratories, Delco transistors must pass numerous electrical and environmental tests both before and after aging. This double testing, combined with five years of manufacturing refinements, enables us to mass produce any type of power transistors with consistent uniformity. And we can supply them to you quickly in any quantity at a low price. For complete information or technical assistance on our versatile application-proved family of transistors, just write or call our nearest sales office or distributor.

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324 Chestnut Street
MURdock 7-3770

Santa Monica, California
726 Santa Monica Blvd.
UPTon 0-8807

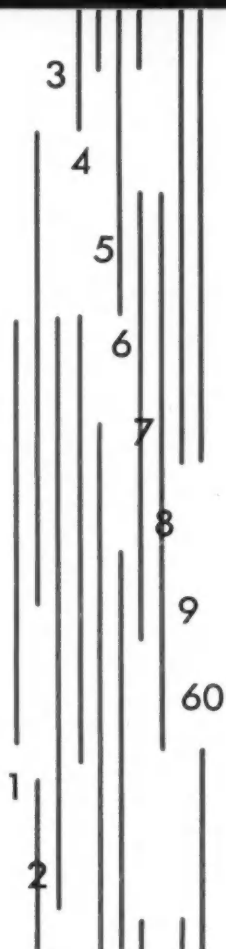
Chicago, Illinois
5750 West 51st Street
PORTsmouth 7-3500

Detroit, Michigan
57 Harper Avenue
TRinity 3-6560

DELCO
RADIO
RELIABILITY

Division of
General Motors
Kokomo, Indiana

verify
events
permanently
in
milliseconds



Brush Operations Monitors' response to signals is virtually instantaneous—less than 4 milliseconds. Multiple high-speed events are clearly defined from start to stop, on a common time base—and at rates up to 500 per second. Portable 30 channel or rack-mounting 100 channel models record sharp reproducible traces with fixed-stylus electric writing that provides the utmost in reliability. "Built-in" transistor switching to eliminate relays is optional. No direct writing recording system can match the capabilities of Brush Operations Monitors for industrial and military analysis and control. Write for complete specifications and application data.

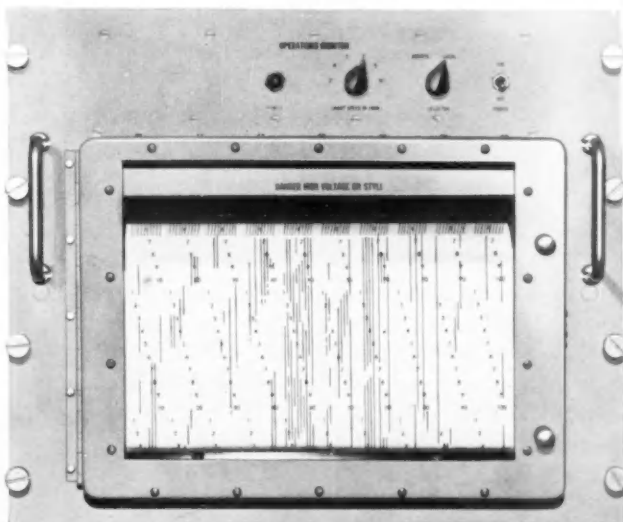
brush INSTRUMENTS

DIVISION OF

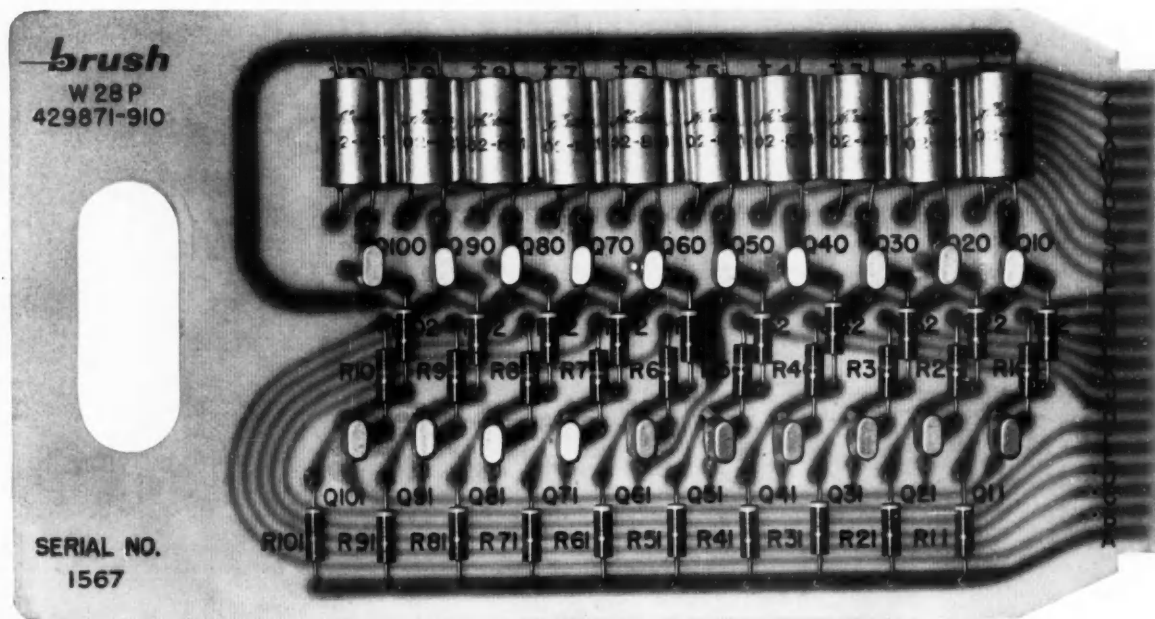
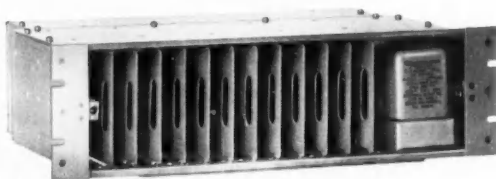
37TH AND PERKINS

CLEVITE
CORPORATION

CLEVELAND 14, OHIO



compact transistor switching for millisecond monitoring



The new Brush Trans-Switcher eliminates relays—greatly simplifies your problems of operations monitoring. Designed to take full advantage of the fast response and high resolution of Brush Operations Monitors, this compact, solid-state switching unit accepts up to 100 different "on-off" signals in a broad range of pulse shapes and amplitudes. Interchangeable, plug-in decade boards are designed to accept different voltage ranges and modes of operation. Avoid the "black box" approach—specify the *standard* Brush Trans-Switcher for the ultimate in precise, reliable monitoring. Write for complete details.

brush INSTRUMENTS

DIVISION OF

37TH AND PERKINS

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CLEVELAND 14, OHIO



NEW PRODUCTS

PROXIMITY SWITCH SENSES both ferrous and nonferrous metals.

High sensitivity to ferrous and nonferrous metals and a low price are features of this Model 501 proximity limit switch. Price for a system of small pickup (1½ x 1½ x 4½ in.) and an electronics unit with an spdt output relay rated at 5 amp, 110 volts ac noninductive load is \$78. Other models range from \$72 (for ferrous metals only) to \$98 (with 250-volt load, mercury output relay) and higher.

Pickup is inductive using ac excitation, so metal chips are not attracted. Metal entering the sensitive area distorts an ac field that is provided by an exciter winding in the pickup. A second winding senses the distortion in the field caused by the metal, and the induced potential operates the relay through an amplifier.

Repetitive accuracy to within 0.010 in. at 4-in. sensing ranges can be achieved. Maximum sensing range is 1 in. for ferrous and nonferrous sheets 0.0001-in. thick or greater, or sheets having dimensions of at least 2 in. square.



Maximum operation rate is more than 30 per sec. The pickup will operate submerged, in contaminated areas, or through shields. Power consumption is only 2 watts.—Electronic Signals, Inc., Cleveland, Ohio.

Circle No. 309 on reply card

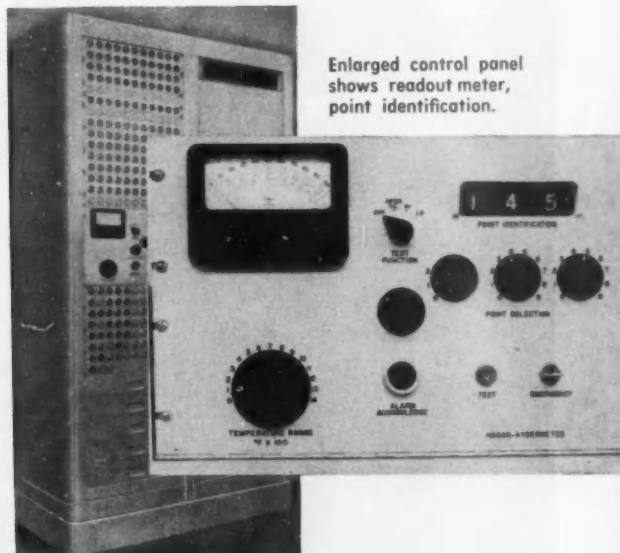
ELECTRONIC MONITOR checks 200 points at 5 per sec rate.

This monitoring alarm system can oversee as many as 200 inputs that can be represented by a dc voltage (as low as 10 mv FS) and at a rate of 5 points per sec will indicate any out-of-limits conditions to the operator. Temperatures, pressures, flows, levels, or contact closures that do not meet preset requirements will result in readout of the point's name on individual indication lights and its number on a digital display panel along with a horn alarm. Horn is silenced by acknowledge button, but light stays on until condition is corrected.

Alarm accuracy of the AIM system (Alarm Indicating Monitor) is to within ±0.1 percent full scale. In addition, manually selected readout on a meter of any point is available continuously with an accuracy to within ±1 percent full scale. Alarm setpoint stability is within ±0.3 percent FS.

Input devices are glass enclosed, sealed reed relays, with anticipated life of billions of operations.—Hagan Chemicals & Controls, Inc., Pittsburgh, Pa.

Circle No. 310 on reply card



Enlarged control panel shows readout meter, point identification.

THIN FILM MEMORIES cycle in 0.2 microsec.

First thin film memory units to be placed on the market as computer components are these BIP-1000 planes with a capacity of 20 eight-bit words. Ideal for "scratch pad" memory functions in data processing systems because of

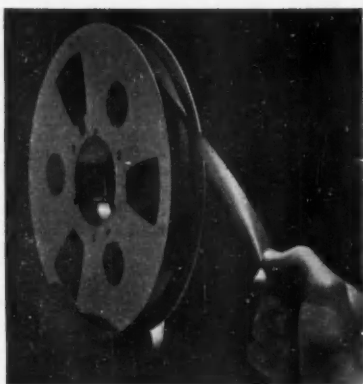
their high speed—0.2 microsec, or about 10 times faster than the cycling rate for the fastest ferrite memories—these deposited film devices also offer the possibility of low prices when volume production is reached. Current price is \$175 for the 160-bit memory. Individual planes can be stacked for greater capacity as desired.

Manufacturing process consists of evaporating nickel/iron alloy spots on a glass substrate to form an 8-microin.

←CIRCLE 170 ON READER SERVICE CARD

A shining example of Ampex leadership!





Again, Ampex has advanced the boundaries of magnetic recording, with computer and analog tapes that set new standards of excellence for the industry.

The shining surface of Ampex tape is mirror-smooth. It glides directly over the recording head—no nonmagnetic layer in-between. Improved head contact means consistently uniform output and brilliant resolution. The revolutionary Ampex binder formulation and the exclusive Ferro-sheen process give Ampex Computer Tape the lowest coefficient of friction of any tape with far less headwear and oxide build-up.

Thus, Ampex offers the first truly **clean** error-free tapes for instrumentation, the first digital and analog tapes to give you long life and optimum performance **without compromising either!** Recent wear tests by an independent company using Ampex's 833 Long Wear—High Output Computer Tape, showed that the first permanent drop-out was not encountered until the tape had passed through the handler more than 400,000 times! In fact, Ampex tape wears 10 times longer than other tapes with comparable magnetic properties.

Rigorous quality control standards assure you error-free tape, that lives up to high Ampex standards. Every reel of Ampex Computer Tape is individually tested. Evaluation of magnetic properties include: Uniformity of Output, Intrinsic Coercivity (H_{ci}), Retentivity (B_r), and squareness Factor ($\frac{B_r}{H_{ci}}$). There are more than 100 quality checks, from raw material to finished product.

Ampex has pioneered in giving the magnetic recording industry the finest equipment possible. New Ampex Computer and Instrumentation Tapes live up to the same high Ampex standards. No matter what your application—data acquisition, reduction or control programming—you will get the most out of your recorder with clean-running Ampex tapes.

Write for specifications and literature.



Ampex Magnetic Tape Products Orr Industries Company

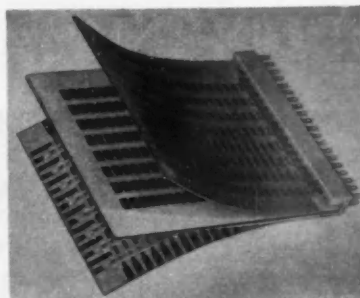
Division of Ampex Corporation • Opelika, Alabama

CIRCLE 173 ON READER SERVICE CARD

APRIL 1961

film. This plate is sandwiched between two printed circuit boards containing read, information, and sense conductors which pass over each bit. Complete, the package measures $4 \times 3\frac{1}{4} \times 0.070$ in. thick.

These thin films are magnetized predominantly by spin-rotation rather than through domain wall movement, as is the case with ferrite memories. The spin-rotational switching is faster; it has been measured in the 10^{-9} sec range. Additional advantages of the thin films are their ability to accept greater drive tolerances than ferrite cores, yield bipolar outputs automatically, and be driven by single polarity pulses for information entry and read-



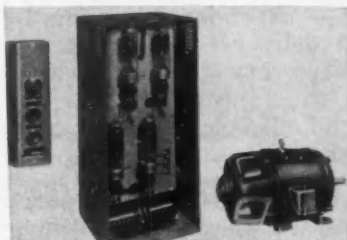
Memory plane fanned to show substrate and circuit boards.

out.—Burroughs Corp., Electronic Tube Div., Plainfield, N. J.

Circle No. 311 on reply card

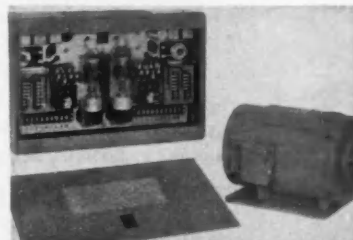
4 NEW ADJUSTABLE SPEED DRIVES

Four adjustable speed drives have been introduced—two electrical, two mechanical. Here's a rundown on their characteristics



Low cost is featured in this electronic adjustable speed drive line available in ratings from $\frac{3}{4}$ to 4 hp. Capable of speed ranges from 2 to 1 up to 100 to 1, the drives operate on single phase ac through a pair of thyristors and diode tubes. IR drop compensation is employed.—Square D Co., Milwaukee, Wis.

Circle No. 312 on reply card



Models rated at 3 and $7\frac{1}{2}$ hp max have now been added to this manufacturer's line of electronic adjustable speed drives which use dc motors powered by two thyristors in a full wave circuit. Magnetic amplifier control will hold rpm within 2-3 percent of set speed.—Cleveland Machine Controls, Inc., Cleveland, Ohio.

Circle No. 314 on reply card



This newly designed line of mechanical variable speed drives includes three models from 1 to 10 hp with a speed range of up to 8 to 1. Standard NEMA C face motors are used. Both drip-proof and totally enclosed constructions are offered.—Industrial Products Div., Western Gear Corp., Belmont, Calif.

Circle No. 313 on reply card



Speed ratios up to 10 to 1, from 4 to 10,000 rpm, are offered in this mechanical variable speed drive available in ratings from $\frac{1}{4}$ to 1 hp. Ease of precise settings is a feature. The Type 5 VA in the $\frac{1}{4}$ -hp size weighs 63 lb and is $14\frac{1}{2}$ in. high by 8 $\frac{1}{2}$ in. wide.—U. S. Electrical Motors, Inc., Los Angeles, Calif.

Circle No. 315 on reply card

FIRST

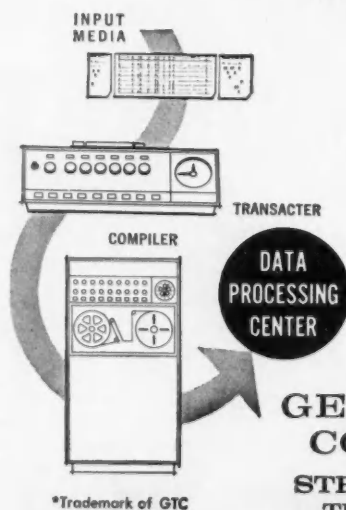
with the Solution

The TRANSACTER* System — the fastest proven method of accurate instantaneous data collection and transmission — provides management with complete data on production status and order location, inventory control, labor costing, tool crib and stores control, receipt and shipment, on-line communication. These are just a few of the many potential assignments for the TRANSACTER System.

Until Stromberg developed the new TRANSACTER System, no accurate, instantaneous method of source data collection existed. Industrial data collection and transmission was a relatively primitive operation — dependent on manual recording and delivery — subject to human fallibility every step of the way. Such methods were incompatible with the accuracy and efficiency of EDP and computer speeds.

The TRANSACTER System eliminates the paper work between widely scattered data sources and a central processing office. Management reports that have taken days — sometimes weeks — can now be produced in minutes! With the TRANSACTER System dramatic new opportunities for profit improvement become evident.

Write for informative booklet.



GENERAL TIME CORPORATION

**STROMBERG DIVISION
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Makers of the World's Finest Time Equipment

174 CIRCLE 174 ON READER SERVICE CARD

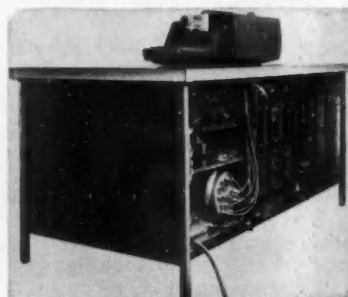
NEW PRODUCTS

SYSTEMS

BLENDS BY MEMORY

Using accurate turbine flowmeters, this blending system combines standard electronic components to remember total amounts of components put into a blend and control the instantaneous total quantity ratio. System can be supplied from two-stream up to multistream versions for as many as 20-component blends. Basic units in the blend controls besides the turbine flowmeters are digital comparators, ratio setters, electronic controllers, diaphragm motor valves. Price for two streams: from \$5,700.—Fischer & Porter Co., Warminster, Pa.

Circle No. 316 on reply card



TYPEWRITER COMPUTER

Shown above in a rear view is the electronics compartment of the Type-tronic 6615, a business data computer with electric typewriter input and output. Programming is by a unique punched Mylar card that is easily inserted in the typewriter mechanism. A magnetic disc memory is used. Time for simple calculations is 17 millisec. Designed to be used with the 6615 is the 2215, a business document writing system, also contained in a desk-sized unit and based on a typewriter. It accepts punched tape or edge-punched card input. The 2215 with one punch sells for about \$4,500; the 6615, with typewriter input/output, for about \$6,000.—Smith-Corona Marchant, Inc., New York, N.Y.

Circle No. 317 on reply card

WEIGHT COMPARISON

Items weighing as much as 5 lb can be automatically weighed and compared within ± 1 gm of a preset

CONTROL ENGINEERING

weight and either accepted or rejected using this production line comparator. Accepted items are automatically passed on to the next production step. System design takes into account factory environments and uses components rated at billions of operations.—Atronic Products, Inc., Bala-Cynwyd, Pa.

Circle No. 318 on reply card



FOR ALGOL, COBOL

The B5000 solid state computer, shown above in scale model, is said to be the first computer designed specifically for automatic programming. ALGOL and COBOL compilers will be standard equipment. Accent in design has not been on computing speed, although add time is only 3 microsec. Monthly rentals will be \$13,500-50,000. Sale price will range from \$540,000 to \$2 million. Delivery time: 18 months.—Burroughs Corp., Equipment & Systems Div., Detroit, Mich.

Circle No. 319 on reply card

ON-LINE COMPUTER

Anatrol is a compact analog computer designed for on-line process control work. With an accuracy from input to output within better than ± 1 percent of full scale, the computer uses a time-sharing technique for step-by step solution of equations according to its program. In this way three amplifiers and one multiplier in a 25-step switching pattern have the potential of at least 75 amplifiers and 25 multipliers. The unit measures only 23.5 x 28 x 15 in. and weighs 180 lb.—Price: about \$8,400.—De Havilland Aircraft, Inc., New York, N. Y.

Circle No. 320 on reply card

DATA HANDLING & DISPLAY

BUSINESS PAGE READER

First reader capable of reading pages of business documents (containing a

hays

RAMBLINGS ON INSTRUMENTATION



TO GET GASSED BY

(A recent letter from our man Melvin, lovable Hays representative in the southern Northeast territory, or is it the other way around?)

Dear Captain Bligh:

I herewith acknowledge receipt of two breathless missives from you. Both are barnburners, in your usual vein. Knowing your proclivity for the practical joke, I have had many a chuckle over the one about my being fired. The other is, apparently, one of your sporadic attempts to whip the sales force into a frenzy. The subject of this particular specimen of purple prose is "Hays is the leader in the continuous gas analysis field!"

While I am still reeling from this shocker, I read on to find there is an insatiable market for our Thermo-Conductivity Analyzer in slaughtering houses and missile silos. For your information, this hardly points to the road to riches for lovable old Melvin. The miserable territory to which I have been exiled has not produced a hog worth slaughtering for 20 years. And the silos hereabouts contain nothing but surplus lichee nuts . . . not a missile in the lot.

What you need, old brontausarus, is a new advertising approach. Think, man, think! What sells gum and soap? Jingles, that's what! I've taken the liberty of jotting down a little ditty.

Now just imagine you are a big processor with a gas analysis problem being roused by your clock radio from a peaceful slumber at 6:30 a.m. to this, with a banjo accompaniment:

If you've got gas
That's tricky to measure
The Hays Condu-Therm
Will double your pleasure.



For argon, nitrogen, NO₂
Xenon, freon—the Condu-Therm's
for you.
Helium, deuterium, and ethylene,
too
Acetylene, plus CO one and two.

Benzene, hexylene, a gang of
methyls

(Like chloride, bromide,
iodide)—and ethyls.

Pentane, propane,
and here's the laugh—
Costs just a fifth of a
chromatograph!

Pretty as a coffin,
Small as a C-ration
Tougher than the boss
Of the Hays Corporation.

In its black satin finish
It's a gasser, son!
Write for bulletin B-
Six forty-one.

I have a couple more verses that punch up such features as no moving parts, no maintenance and pinpoint accuracy. They need a little polishing but I'll shoot them on as soon as they're ready.

As an afterthought, in case that laughable note about me being fired had any connection with my last expense account, I thought I had explained that fully to Mr. Feeney. But perhaps the circumstances that led to the charter of a one-horse sleigh and the replacement of the Civil War cannon in Sauk Junction Park can best be discussed face to face the next time I am called in for an injection of home office wisdom.

Yours more in sorrow
than in anger,

Melvin

P.S. If you decide to put my jingle on the air, better print an extra supply of bulletin B-641.

The A. Spagor

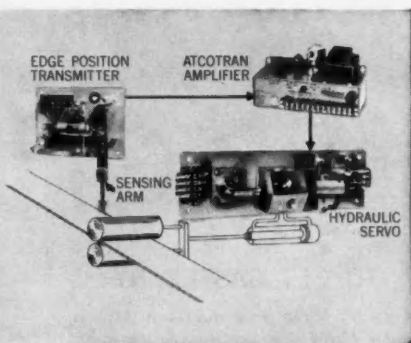
President

THE HAYS CORPORATION • MICHIGAN CITY, INDIANA

DISPLACEMENT PICK-UPS FOR MACHINE AUTOMATION

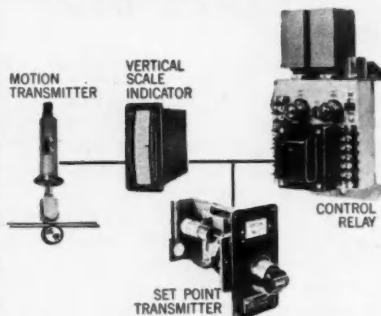
EDGE CONTROL

Atcotran Edge Guide Control maintains constant, precise edge positioning (within 0.001") for accurate register of moving web. Range is 2 1/4" with only 1/4 oz. pressure on edge. Stable null balance circuit. For paper, metals, textiles, plastics, etc.



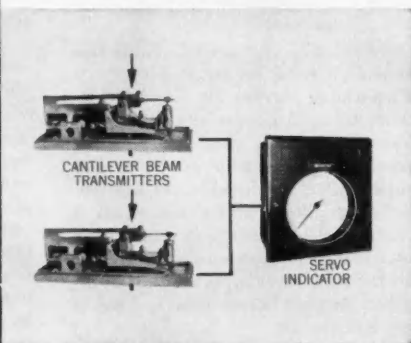
THICKNESS MEASUREMENT

ATC measuring devices for reliable automation control systems. Indicates and controls thickness to adjustable pre-set tolerance. Ideal for wallboard, sheet metal, plywood, plate glass, etc.



WEIGHT SUMMATION

ATC Cantilever Load Cells change force (or weight) to electrical signal, recorded as weight on servo indicator. Multiple load cells may be algebraically coupled for indication-control of force, thrust, torque, etc.



ADVANCED DIFFERENTIAL TRANSFORMER PRINCIPLE permits simple and rapid automation of machine functions using standard off-the-shelf control components, indicators, recorders, and process controllers. Discuss your applications and requirements with your ATC representative.



Send for literature on Atcotran Differential Transformer Experimental Kit—today!



AUTOMATIC TIMING & CONTROLS, INC.
KING OF PRUSSIA, PENNSYLVANIA

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ATC, Div. of Interprovincial Safety Industries, Ltd., 5485 Notre Dame St., West, Montreal 30, Quebec

176 CIRCLE 176 ON READER SERVICE CARD

NEW PRODUCTS

special font of type) and translating the information into punched paper tape has recently been introduced. The Model 10DP2 optical scanner reads a nominal 8 1/2 x 11 in. page at 2 1/2 lines per sec and punches the data into tape at 240 alphanumeric characters per sec. Later models will supply output on magnetic tape—at 340 characters per sec. Automatic feed is used, allowing 30 pages to be stacked. Price ranges from \$125,000 to \$200,000 depending on special features.—Farrington Manufacturing Co., Data Processing Div., Needham Heights, Mass.

Circle No. 321 on reply card



48-CHANNEL DATA HANDLER

A mobile data handling system only 4 ft high can collect, process, and prepare information for direct entry into most common computers. Called RADAC I, it is composed of a multiplexer, coder, digital logic circuits, tape transport, and power supplies. The system handles up to 48 analog inputs with a resolution to ± 10 microvolts and accuracy to within ± 0.1 percent. Maximum word rate is 3.8 kc. Price: less than \$60,000 without accessories. Optional features include digital or analog quick look recorders, automatic run controls, and remote controls.—Radiation, Inc., Melbourne, Fla.

Circle No. 322 on reply card

IMPROVED MODEL

Frequency response has been extended 20 percent (to 1.2 Mcps at 120 ips) and the capability of accommodating 14 tracks has been added to this manufacturer's CM-100 video band recorder/reproducer. The magnetic tape unit previously had response to 1 Mcps at 120 ips; response at all six speeds has been proportionately increased, to 600 kcps at 60 ips, for instance. Also, the single rack, seven-track CM-100 is now easily converti-

CONTROL ENGINEERING

ble to 14 tracks by plugging in an additional rack of electronics equipment. Same over-all bandwidth of 400 cps at 1.2 Mcps is achieved simultaneously on all 14 tracks. As with the original model, the new version is capable of recording both pulse and analog signals.—Mincom Div., Minnesota Mining and Manufacturing Co., Los Angeles, Calif.

Circle No. 323 on reply card



HANDY RECORDER

Only 2 x 4 x 5 in., this magnetic tape recorder is small enough to be fitted in a flight suit or carried in a coat pocket. The three-channel instrument weighs only 31 oz including 7 oz of tape and can record a minimum of 1 hr at 1½ ips. Frequency response is flat within ± 3 db from 100 to 5,000 cps with negligible flutter and wow, and signal to noise ratio is better than 30 db. The recorder's ¾-watt power requirement can be supplied by a standard mercury cell or other low impedance power source. It was designed for dynamic recording in the range from 1,000 to 5,000 cycles. Manufacturer claims it is operable in any environment where man can exist and accuracy is unaffected by position or motion. Price: \$3,500.—Precision Instrument Co., San Carlos, Calif.

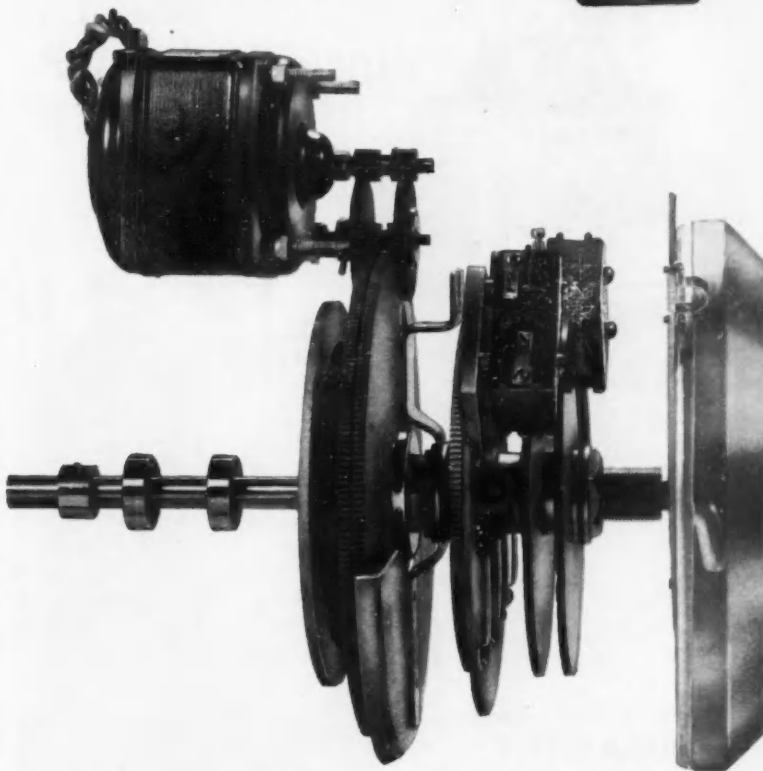
Circle No. 324 on reply card



ELIMINATES SERVOS

This 30 x 30 in. X-Y plotter is engineered in such a way that standard

For the best in process control, see L&N



Behind Speedomax® G performance: STURDY MECHANICAL CONSTRUCTION

Why do Speedomax G users so often mention its excellent reproducibility . . . reliable accuracy . . . uninterrupted operation?

One of the reasons is the instrument's sturdy mechanical construction. The direct-drive measuring shaft keeps the split drive-gear, measuring slidewire contacts and any signalling, control, and/or re-transmission contacts in rigid alignment. There's no backlash, no dead space. The result: accurate records, precise control.

Additional mechanical features include: pointers and scales that pro-

vide excellent setability and readability . . . die-cast case, door, main frame and chart table . . . machine-cut gears and ball bearings. All contribute to the instrument's "staying power" under adverse conditions.

Such ruggedness is particularly vital in heavy industries where Speedomax G control systems are measuring and regulating temperature, pH, speed, mechanical and electrical load, and other quantities. For information on Speedomax G, or on any of our products and services, call your nearest L&N office or write 4918 Stenton Avenue, Philadelphia 44, Pa.

LEEDS  **NORTHROP**
Instruments Automatic Controls • Furnaces

Pioneers in Precision

what's so different
about these
time/delay/relays?



(and how these
AGASTAT
differences benefit
you!)

AGASTATs are electrically actuated, but are *pneumatically* timed, so their accuracy and reliability are unaffected by voltage variations, and recycling is instantaneous. Adjustment is simple and stepless over l-o-n-g time ranges. With moving parts held to a minimum, the life span of a typical unit is measured in millions of cycles.

Industrial models (left) are dial-adjusted for delays of .05 sec. to 15 min. in five ranges. Needle valve models are also available, covering the full range (.15 sec. to 5 min.) in one unit. The Miniature Agastat on the right weighs as little as 15 oz. Hermetically sealed or unsealed types for MIL Spec or other demanding applications. Saves weight, saves space.

Timing accuracy and reliability are what you would expect from AGASTAT, pioneers in the development of time delay instrumentation. Single- or double-pole versions, in all standard AC and DC coil voltages. Types to provide delay on pull-in or drop-out. Want complete specs, or further information? Just write Dept. II-34.



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ELIZABETH DIVISION • ELIZABETH, NEW JERSEY

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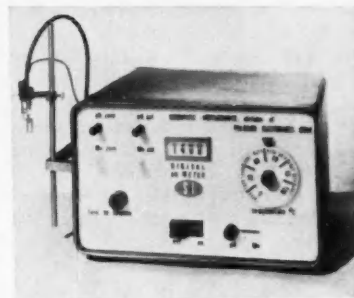
178 CIRCLE 178 ON READER SERVICE CARD

NEW PRODUCTS

servomechanism drive is eliminated. With an error of only 0.05 percent of full scale, the solid state device repeats from any direction. Input can come from punched cards, punched tape, or keyboard with slewing speed of 20 ips. Printing head contains 12 symbols, but other print sectors can be added to plot digital or symbol information. Models are available up to 48 x 48 in. The one shown above comes with keyboard, tape and card input, and facilities for setting scales on one X and one Y channel with additional Y channels optional and sells for \$14,975.—Gerber Scientific Instrument Co., Hartford, Conn.

Circle No. 325 on reply card

RESEARCH, TEST, & DEVELOPMENT



SHOWS REDOX REACTIONS

Line fluctuations as high as 10 percent will not affect the accuracy of this automatic self-balancing pH meter that features a digital readout. There is, in addition, a millivolt scale to record redox reactions. Any type of electrode can be accommodated and an external recorder may be plugged into the unit for continuous monitoring. Temperature compensation is also provided. The full range of 0 to 14.00 pH is covered with an accuracy within 0.02 pH units.—Scientific Instruments Div., Polarad Electronics Corp., Long Island City, N. Y.

Circle No. 326 on reply card

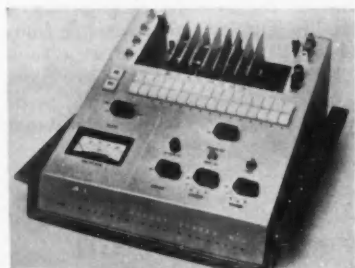
FUNCTION ANALYZER

A cross-spectral density computation technique is used in this function

CONTROL ENGINEERING

analyzer to determine the response characteristics of control, structural, and servo systems, as well as electric networks. The device takes up the space of two 70-in. high standard relay racks, gives output as Nyquist or Bode plots, and operates with driving signals that are random or complex periodic in nature. In addition, it is said to be able to obtain the exact causal relationship between two signals even when the relationship is obscured by extraneous noise. Depending on options, the price is \$25,000-30,000.—Ortholog Div., Gulton Industries, Inc., Metuchen, N. J.

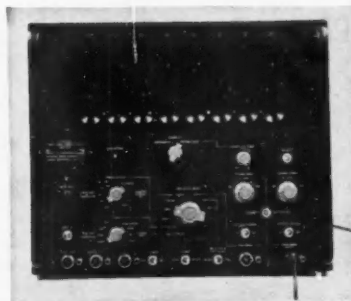
Circle No. 327 on reply card



TESTS DIGITAL MODULES

As simple to operate as a drugstore tube tester, this digital module tester can make complete tests of all 200-kc and 3-Mc magnetic modules and modules from the manufacturer's PB 250 computer. Tests include input pulse amplitude, duration, rise time, and repetition rate plus output resistive and capacitive load. The tester also checks its own signal generating cards. Basic tester price is \$1,950.—Packard Bell Electronics, Los Angeles, Calif.

Circle No. 328 on reply card

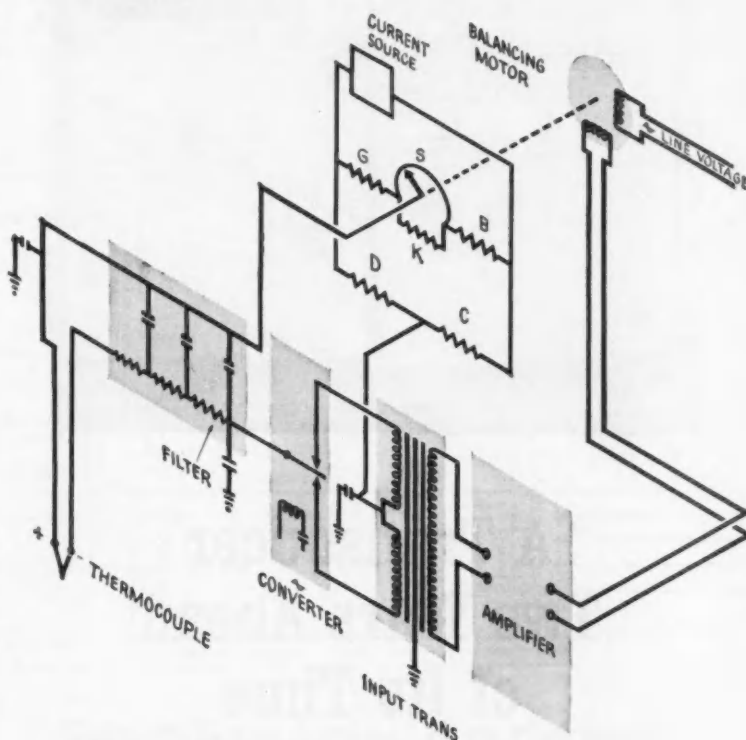


REMEMBERING COUNTER

This digital time and frequency meter (counter) features the capability to remember the intermittent count of four of its eight counting digits to provide a four-digit continuous read-



For the best in process control, see L&N



Behind Speedomax® G performance: NULL-BALANCE MEASURING SYSTEM

What leads Speedomax G users to expect — and *get* — fast response . . . fast balancing . . . fast control action?

One reason is the instrument's null-balancing system. Skillful engineering attention to amplification, circuit protection and damping, response and sensitivity provide the swift get-away and the sure braking required for precise, reliable control.

The basic "general-purpose" amplifier, for example, uses four stages of amplification . . . and sensitivity is such that a 5-microvolt unbalance in the overall measuring circuit — in-

cluding the recorder slidewire, external source resistance of 2000 ohms, detector and filter — will produce 20 volts on the control winding of the balancing motor . . . providing more than enough torque for positive balancing action even under adverse conditions.

Speedomax G's get-away and braking power are particularly important wherever precise process control is a "must". For information on Speedomax G, or on any of our products and services, call your nearest L&N office or write 4918 Stenton Avenue, Philadelphia 44, Pa.

LEEDS NORTHROP
Instruments Automatic Controls • Furnaces
Pioneers in Precision



A Transducer Two Years Ahead of its Time

A completely new patented pressure Servonic's new, low pressure L-96 ometer-type unit withstands vibration than 1% error. Two separate sets of ends of a driving frame are utilized driving media while the second can sure reference, or vented to the



sensor concept has been utilized in Transducer. This miniature potenti- levels in excess of 35 g's with less aneroid capsules attached to opposite in the design. One set senses the be evacuated for an absolute pres- atmosphere for gage measurement.

Pressure changes are transmitted through a unique, frictionless, metallic belt linkage system to position the wiper of the precision potentiometer. The fluid filled interior dampens vibration effect, provides long life and minimizes electrical noise. The unit is so insensitive to vibrations, extended dwells are allowed at any vibration frequency. Besides its excellent vibration characteristics, the L-96 has a temperature range of -65° to 275° F and a range of 0-15 to 0-350 psia or g.

For additional information about the wide pressure ranges and mounting configurations available in the L-96, write:

SERVONIC INSTRUMENTS, INC.

Manufacturers of pressure transducers, pressure switches, rectilinear potentiometers and slip ring assemblies.

1644 WHITTIER AVENUE, COSTA MESA, CALIFORNIA

NEW PRODUCTS

out while the other four continue counting. Full eight-digit intermittent readout is selectable. Also stressed is high reliability obtained through circuit design that uses a fool-proof counting method—unlike that of other counters—and that is capable of operating on half-dead tubes and at ± 10 percent off rated voltage. Measurement ranges are: frequency, dc-10 Mc; period, 10 microsec to 10^7 sec; time interval, 1 microsec to 10^7 sec. Sensitivity is to 0.25 volts rms, and accuracy is to within ± 1 count plus or minus time base oscillator stability. Display time is variable from 0.1 to 10 sec. Complete with time base stable in the short term to 5 parts in 10^6 per min, price is \$2,950, without time base: \$2,585.—General Radio Co., W. Concord, Mass.

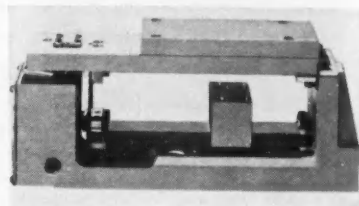
Circle No. 329 on reply card

RECORDING SIMULATOR

Now available is a digital recording simulator priced at less than \$1,000 that makes possible complete analysis of any digital drum, disc, or tape recording system at frequencies to 600 kcps. RZ, NRZ, or phase modulation signals can be recorded at record amplifier impedances from 50 ohms to 2 kilohms, with power sources from 5 to 50 volts, and wide peak recording currents to 270 ma. Included is a calibrated playback amplifier with any sensitivity down to 10 microvolts for low level recording. — Magne-Head Div., General Instruments Corp., Hawthorne, Calif.

Circle No. 330 on reply card

PRIMARY ELEMENTS & TRANSDUCERS

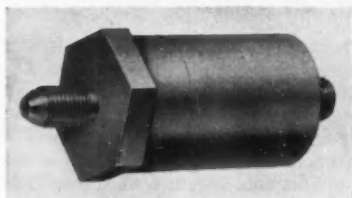


SENSES VARYING FORCES

Tension, pressure, weight, and thrust can be measured by this force trans-

ducer. The device monitors forces developed in any direction and converts mechanical displacement to an electrical output which in turn brings about corrective action. For example, this transducer will maintain the proper tension in a fast moving continuous metal strip. Key to the operation is a system of cross-spring (flexure) pivots combined with a flat, cantilever main spring. Standard models will take loads from 8 oz to 1,500 lbs. According to the manufacturer, overload will not damage the unit or cause any shift in calibration. Model for 500 lb max force sells for \$550.—Hydro-Pneutronics, Inc., Force Transducer Sales Div., Cleveland, Ohio.

Circle No. 331 on reply card



DIGITAL TRANSDUCERS

Input to these new transducers can be from several primary energy sources: pressure, temperature, acceleration, flow rate, etc. These analog signals are converted by the device into true digital signals by a solid state converter. Outputs can have PDM, PPM, or PFM time base. Digital output is pre-calibrated to the measured parameter without zero suppression; e.g., 0-1,000 microsec (PDM or PPM) can be made to indicate 0-1,000 psi. Transducers are available to measure 5-8,000 psi. Minor revisions can convert them to temperature or acceleration measurement. Unit measures 2 in. in diam by 2 in. Conversion linearity error is ± 0.5 percent, repeatable within 0.2 percent. Output signal is 5 volts or more into a 50-kilohm load.—DeJur-Amsco Corp., Long Island City, N.Y.

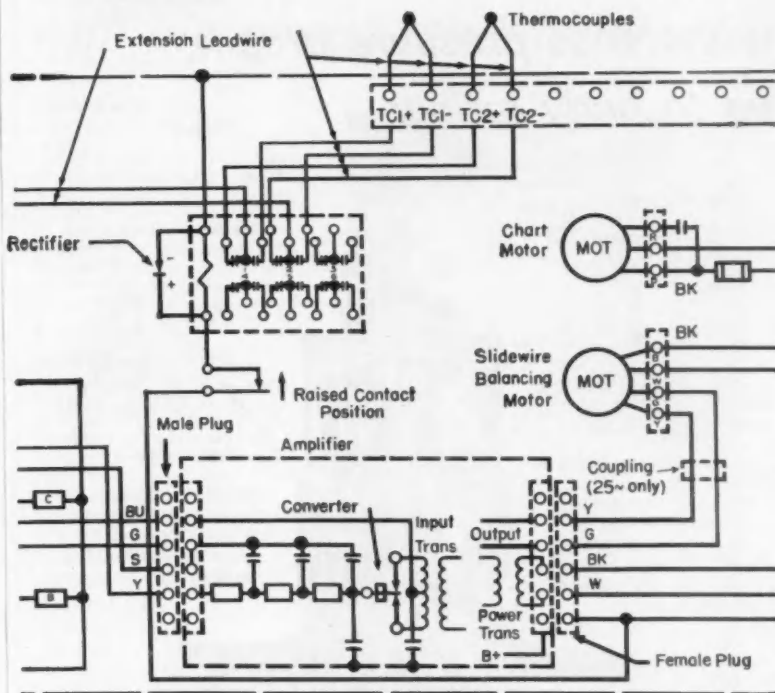
Circle No. 332 on reply card

MACHINERY MONITOR

This photoelectric device will warn of the slowing down or stopping of machinery used in continuous processes by sensing changes in rotation or other movement. Repeated regular interruptions of a light beam maintain a relay energized; if the interruptions stop or fall below a preset speed, the relay will initiate corrective action or give an alarm. Any machinery can be monitored, including conveyors, rotating shafts, rolls, crank arms, etc.



For the best in process control, see L&N



Behind Speedomax® G performance: CLEAN MEASURING CIRCUITS

Why does Speedomax G maintain its precise calibration for so many years, even under difficult service conditions?

One of the reasons is the care taken in the development and manufacture of Speedomax G measuring circuits. Over 300 circuits are available . . . and each takes maximum advantage of electronic null detection, non-inductive wiring and proper shielding.

Significant features include soldered connections . . . slidewire resolution to back up the 0.1% recorder sensitivity . . . 100% inspection of slidewire uniformity . . . the use of manganin resistors.

So that any error can be detected and corrected before shipment, extensive accuracy checks are made both before . . . and after . . . the instrument goes on its several-day test run. You'll find that Speedomax G meets or exceeds the performance requirements of ASA Specifications 39.4-1956.

The importance of clean, reliable circuitry is demonstrated daily in Speedomax G applications involving advanced research, data-handling, and systems control. For information on Speedomax G, or on any of our products and services, call your nearest L&N office or write 4918 Stenton Ave., Philadelphia 44, Pa.

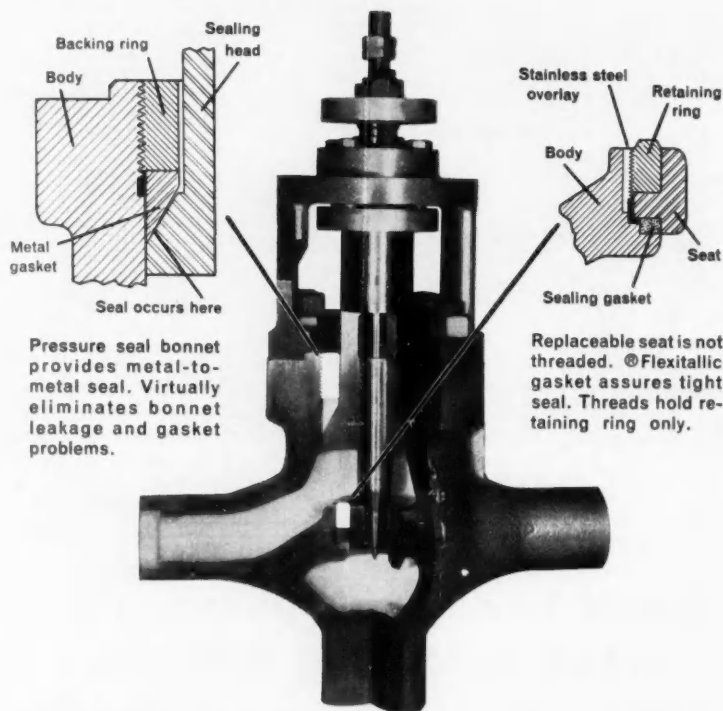
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ROCKWELL-REPUBLIC

High pressure globe valve withstands pressure drops up to body ratings



Pressure seal bonnet provides metal-to-metal seal. Virtually eliminates bonnet leakage and gasket problems.

Rockwell-Republic high pressure globe valves are available in 1½", 2", and 3" sizes for 1500, 2500 and 4500 psi standards. In addition to removable seat and pressure seal bonnet, these valves are available with bolted bonnets and quick-change trim. For more information about this and other Rockwell-Republic components and systems, just mail the coupon below.

RF-23



Please send latest literature on the following:

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| <input type="checkbox"/> Desuperheating & Pressure Reducing Systems | | |
| <input type="checkbox"/> Electronic Control Systems | <input type="checkbox"/> Pneumatic Control Systems | |

Name _____ Title _____

Company _____

Address _____

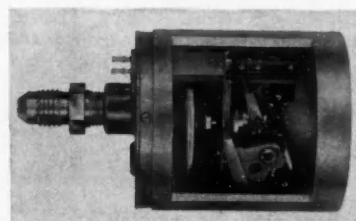
City _____ Zone _____ State _____

Republic Flow Meters Co. (Subsidiary of Rockwell Manufacturing Company)
2240 Diversey Parkway, Chicago 47, Illinois

NEW PRODUCTS

The unit is dust-tight and fail-safe. Price: about \$70.—Hird-Brown Ltd., Sale, Cheshire, England.

Circle No. 333 on reply card



RUGGED PRESSURE SENSOR

Designed to measure pressure in the ranges of 0-5 and 0-500 psi, the TP-200 is suitable for use with corrosive or noncorrosive gases or liquids. The device is potentiometric and uses a temperature compensated mechanical amplification system. This combines the advantages in accuracy and large output of the potentiometer with the reliability, responsiveness, and ruggedness of a capsular N-span-C diaphragm.—Fairchild Controls Corp., Sub. of Fairchild Camera and Instrument Corp., Hicksville, N.Y.

Circle No. 334 on reply card

PLUS . . .

(334) High frequency response over a wide temperature range is combined with light weight and small size in a gas damped unbonded strain gage accelerometer introduced by Statham Instruments, Inc., Los Angeles, Calif. . . . (335) A new rate gyro available now from the Precision Products Dept. of Nortronics, Div. of Northrop Corp., Beverly Hills, Calif., incorporates a dynamic self-testing feature so that it will supply, on demand, information that the spin motor is at synchronous speed and that the gimbal is free to operate.

Circle Nos. 335 or 336 on reply card

CONTROLLERS, SWITCHES & RELAYS

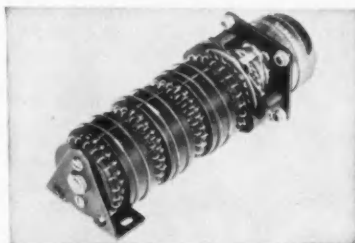
MILLIG SWITCH

This acceleration sensing switch was designed primarily for operation in

CONTROL ENGINEERING

the low ranges, 0.1 to 5 g. Gas damping provides the proper delay or integration before switch closure, and because this damping is virtually independent of temperature, no heaters are needed and there is no warmup time. Normally mounted level, the switch responds to gravity and can be used as a tilt switch since its threshold value is equivalent to a tilt angle of $8\frac{1}{2}$ deg. The makeup of the switch, including springs, mass, damping, and material, can be varied to meet user requirements.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

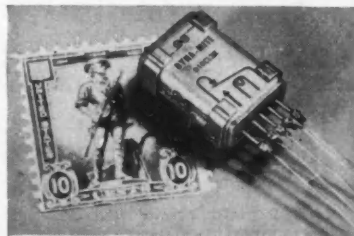
Circle No. 337 on reply card



ROTARY REED SWITCH

Reed switches have been mounted in circular sections to make up these compact rotary units. Heart of the rotary switch is the hermetically sealed cantilever-type contact. In each switch are two gold plated wires which make contact when their polarity is reversed by a magnet. Each switch section is $1\frac{1}{2}$ in. in diam and $\frac{3}{8}$ in. long and can be stacked adjacent to a common shaft. The unit in the picture above is a six-pole, 12-position unit that is 5 in. long including drive motor, three switching units, and end cap. Switch can operate at 15 steps per sec. Because of the strong force holding the contacts closed the switch is reported to have good closed contact performance under vibration. Contact life is 10 million operations at 0.1 amp. Price for one-pole, 12-position switch: \$79.—Hathaway Instruments, Inc., Denver, Colo.

Circle No. 338 on reply card



MITE-SIZED RELIABILITY

The tiny precision relay shown above measures only 0.2 x 0.4 x 0.6 in. and



ROCKWELL-REPUBLIC

V-5 gauges combine small size with big-gauge readability

TRY THIS "CUTOUT TEST"

For a true demonstration of the readability of Rockwell-Republic V-5 gauges, cut out the actual-size photo at the right. Mount it on any wall or panel board. Step back and see how easily the scale can be read, even from 10 or 12 feet away!

BIG-GAUGE ACCURACY, TOO

Compact V-5 gauges are equipped with electric receivers or full sized diaphragms, bellows, and helixes for maximum accuracy and sensitivity. Yet these Rockwell-Republic gauges require one-fourth the panel space needed for standard gauges.

GROUP MOUNTING INCREASES VERSATILITY

As many as eight gauges can be grouped in a single mounting case. Types can be mixed to meet individual panel requirements. Mounting is simple, too. Just a panel cutout is required in most cases.

There's a V-5 gauge for almost every process measurement. Mail the coupon today for the 12-page bulletin on these easy-to-read gauges, and for available literature on other Rockwell-Republic instruments, controls, and valves. RF-22



REPUBLIC INSTRUMENTS AND CONTROLS

more fine products by

ROCKWELL

Please send latest literature on the following:

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| <input type="checkbox"/> Computing Relays | <input type="checkbox"/> Control Stations | <input type="checkbox"/> Recorders |
| <input type="checkbox"/> Flow Meters | <input type="checkbox"/> Drive Units | <input type="checkbox"/> Control Valves |
| <input type="checkbox"/> Desuperheating & Pressure Reducing Systems | | |
| <input type="checkbox"/> Electronic Control Systems | <input type="checkbox"/> Pneumatic Control Systems | |

Name _____ Title _____

Company _____

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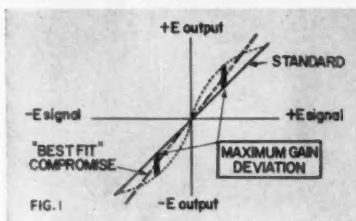
City _____ Zone _____ State _____

Republic Flow Meters Co. (Subsidiary of Rockwell Manufacturing Company)
2240 Diversey Parkway, Chicago 47, Illinois

AMPLIFIER LINEARITY

The linear d-c amplifier reproduces the input signal exactly over the full dynamic range. Negative feedback and careful component choice make possible close approaches to 100% d-c amplifier linearity.

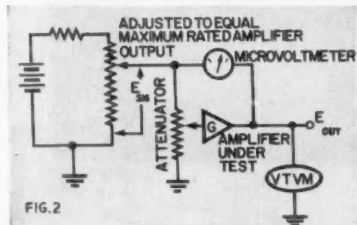
Non-linearity is here defined as the *maximum gain deviation*, over the entire amplifier range, from an ideal straight line passing through Cartesian co-ordinate origin. The graph (Fig. 1) indi-



cates this as well as what is known as the *best fit* method of measurement. The latter splits the error. This discussion refers to the maximum gain deviation technique. Generally speaking an amplifier with 0.02% non-linearity is considered good.

D-C Amplifier Linearity Test

A null-indicating test set-up is shown in the schematic (Fig. 2). Here, an attenuator is inserted between a d-c signal and the amplifier input. This d-c signal is made equal to maximum rated output of the amplifier under



test. The attenuator reduces the signal by an amount equal to the amplifier gain. As a result, under linear conditions, the amplifier output and d-c signal, prior to the attenuator, are equal. This zeros the zero-center reading 0-10 microvoltmeter connected between the amplifier output and the d-c voltage. Any meter deviation is due to amplifier non-linearity. An

X-Y recorder facilitates this test. For more detail, write for BEAN 124.

AccuData III has 0.005 Per Cent Non-Linearity!

The AccuData III is the latest of Honeywell's data handling amplifiers. This all-transistor, wide-band differential input, chopper-stabilized d-c amplifier has the lowest non-linearity of any amplifier in its field.

The AccuData III has single-ended as well as differential input ranges, input impedance of 2



megohms differential (20 megohms single-ended), and power output sufficient to drive the highest frequency galvanometer oscillograph to its maximum deflection. In addition to exceptional linearity, the AccuData III offers excellent drift characteristics, very low noise, and frequency response to 20 kc. Write for Bulletin BS DISA-3 to Minneapolis-Honeywell, Boston Division, Dept. 3, 1400 Soldiers Field Road, Boston 35, Massachusetts.

Honeywell



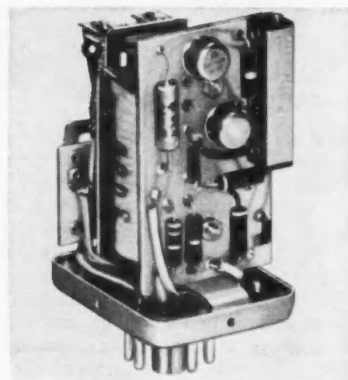
First in Control

SINCE 1885

NEW PRODUCTS

weighs only 0.1 oz. Thus it is about 1/10th the volume of standard micro-miniature relays and compares with their weight of about 0.5 oz. In addition, this new Dyna-Mite relay has proved its performance under vibration of 45 g at 2,000 cps (though nominally rated at 20 g), withstood 100-g shock, and is designed to operate over an ambient temperature range of -65 to +125 deg C. The device is rated at 0.25 amp with a contact life of 10,000 cycles at rated resistive load of 28 vdc.—Control Dynamics Corp., No. Hollywood, Calif.

Circle No. 339 on reply card



TIME DELAY'S ADJUSTABLE

These adjustable time delay relays feature four timing ranges from 50 milli-sec to 60 sec, along with four contact arrangements and two mounting styles. Units utilize a relay together with an adjustable RC time circuit and a two-stage transistor amplifier. Power requirements are 18-32 vdc at 10 ma nominal. Reset time is about 5 percent of operate delay time when power is removed or less than 20 millisecc max with an external pushbutton. Price: \$30-60.—General Automatic Corp., Union City, N. J.

Circle No. 340 on reply card

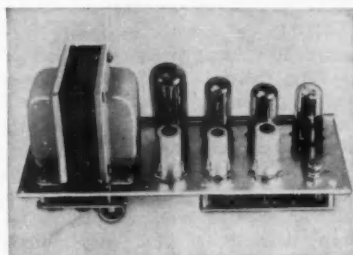
POWER SUPPLIES

COMPUTER POWER

Accurately regulated 400-cps voltage for rectifying to the various dc voltages needed for transistorized com-

puters is produced by this three-unit, brushless design motor-alternator. Use of 400 rather than 60 cycles will result in smaller transformer-rectifiers and filter network components. The unit will reduce the need for repeat programming to correct errors caused by transients in 60-cycle power lines. The supplies consist of a 60-cycle induction drive motor, a wound field synchronous generator, and a rotating exciter-rectifier. They are available with continuous output ratings of from 1 to 5 kva.—General Electric Co., Schenectady, N. Y.

Circle No. 341 on reply card



GIVES CLOSE REGULATION

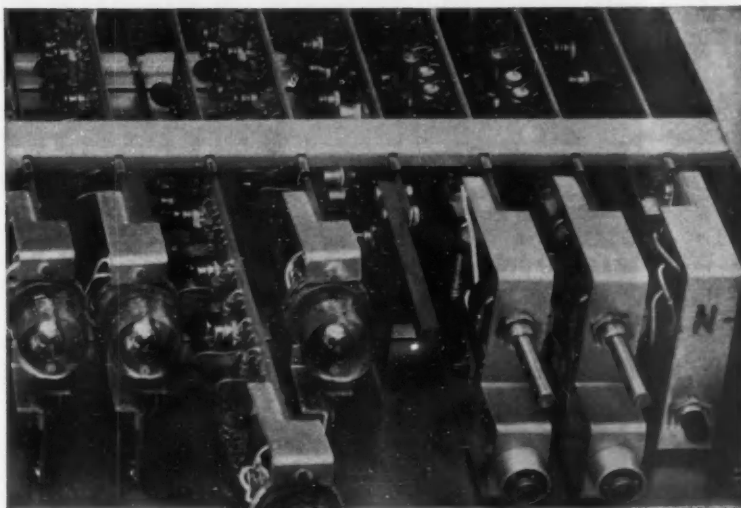
Delivering 150 to 425 vdc at 100-400 ma, this modular power supply designed for mounting in other equipment is claimed to have less than 1 mv ripple with either terminal grounded or both terminals floating. Output regulation is to within 0.05 percent line and load. Two or more units can be joined to give outputs up to 850 volts at 1,800 ma. All units will mount on a 2-in. wide chassis.—Calmag, No. Hollywood, Calif.

Circle No. 342 on reply card



SHORT CIRCUIT PROTECTED

This solid state dual power supply features short circuit overload protection such that the supply is not damaged by even a prolonged short circuit because the short circuit current is always less than full load. The Model 6033 operates from 115 vac and provides two fixed outputs, plus and minus 15 vdc, each at 200 ma. Line and load regulation are to within 0.01



THIS IS WHERE IT COUNTS

NEW ERIE SOLID STATE 500T BI-DIRECTIONAL CONTROL COUNTER

This is a rugged high-speed control counter with bi-directional capabilities for digital closed loop control. It offers for the first time anti-coincidence circuits for random add/subtract inputs, a digital-to-analog converter and an excess error alarm. The instrument has true modular construction in which individual circuit boards are readily inserted from the front for functional versatility and ease of maintenance. In-line NIXIE readout can be supplied when required.

The unique anti-coincidence circuit used prevents interference between add and subtract pulses arriving simultaneously. This provides absolute accuracy as opposed to conventional anti-coincidence circuits. The analog output is proportional in both magnitude and polarity to the algebraic sum of the add and subtract inputs. The readout indicates the instantaneous algebraic sum.

For example, where the 500T is used for control of motor speeds, the pulses arrive at both the add and subtract inputs at exactly the same rate when the controlled motor is running at the desired speed. Any speed change develops an analog output to a servo system which returns the motor to the proper speed. The same basic process would apply to the mixing of liquids or chemicals.

Applications for the 500T are virtually unlimited since it provides digital control of such parameters as flow, speed, position, and many others. An industrial case is available for applications in rugged environments.



Rack Mounting Model



Industrial Model

Complete technical information available on request.



ERIE PACIFIC, DIVISION OF
ERIE RESISTOR CORPORATION
12932 S. Weber Way, Hawthorne, California

2000°F

450°F

Get precise temperature measurement and control the low-cost easy way...

...insist on RdF STIKONS & STRAPONS



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RdF STIKON
New APM
Series



RdF STRAPON
RN-100



RdF STRAPON
RNM-100-1



RdF INDICATORS

RdF STIKON® resistance thermometers for surface temperature measurement were pioneered by RdF Corporation (formerly Arthur C. Ruge Associates, Inc.). These versatile transducers are characterized by millisecond response, high sensitivity, accuracy, stability and high output. Recent developments in adhesives now make it possible to bond RdF STIKONS easily and quickly to virtually any surface. Available in a wide variety of grid styles and carrier materials. Latest addition to the line is the APM Series with temperature ratings of -450° to 2000°F .

RdF STRAPON resistance thermometers, a modification of the RdF STIKON, are mounted on a stainless steel shim overmolded with silicone rubber. These rugged, re-usable sensors can be strapped to the outside of a pipe to measure the temperature of fluid inside without shutting down a process, interrupting flow or cutting holes in pipes. RdF STRAPONS are designed to operate at continuous temperatures from -100° to 500°F .

RdF PROBES—To supplement the established capability of RdF resistance thermometers for surface measurements, RdF Corp. offers a complete line of standard, mounted and miniature probes for measuring temperature in any situation.

RdF PORTABLE INDICATORS—A series of low-cost, direct-reading temperature indicating instruments for use with RdF resistance thermometers. Easy to use, accurate, dependable. Battery or AC power supply optional.

If you have a temperature measurement/control problem, contact us for the name of your nearest RdF sales engineer. Write today for RdF STIKON Catalog and Price List #T-59 and for RdF Products Bulletin #T-60A.

RdF Corporation
Hudson, New Hampshire

Nashua, N.H., TUxedo 2-5195 TWX NASH 188-U

NEW PRODUCTS

percent; ripple is under 1 mv (0.003 percent). Because of great stability, the supply would constitute the basic reference of a control or instrumentation system. Price is about \$285 depending on physical configuration.—George A. Philbrick Researches, Inc., Boston, Mass.

Circle No. 343 on reply card

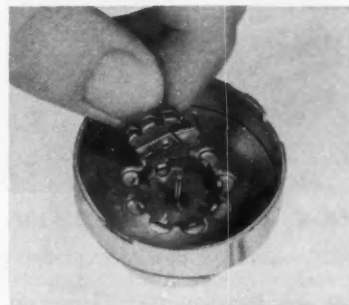
PLUS . . .

(344) Large power capability (25 watts—50 volts at 500 ma) is delivered by the Model AMSF-50-5 power supply measuring only 2.5 x 3.5 x 5 in. and now available from Valor Instruments, Inc., Gardena, Calif. . . .

(345) Christie Electric Corp., Los Angeles, Calif., has announced a compact general purpose, wide range 30-amp dc supply that uses silicon controlled rectifiers to offer voltage regulation within ± 0.5 percent and ripple of only 1 percent rms. . . . (346) A price of \$225 has been placed by Dynex Industries, Inc., Syoset, N.Y., on its high efficiency (90-95 percent) dc power supply Model D-20HE for airborne use that gives well regulated, low ripple output from 24-32 volt battery input.

Circle Nos. 344, 345, or 346 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



L-SHAPED POLE ARM

If the pole arm of this synchronous motor should stop on dead center, the motor will not fail to start again, according to the manufacturer. The unit is said to be the only permanent mag-

net type of motor on the market with this new pole arm design feature. Should the pole stop on dead center, magnetism induced in the variable pole arm by the field coil will start the rotor moving. This gives both permanent and alternating polarity to the rotor. Program timers, computers, and displays are some of the uses for this high torque motor. Standard motor speeds available range from 1/60 to 10 rpm with the standard motor rated at 20 oz-in. and the high torque model rated at 40 oz-in.—Lake City, Inc., Sub. of Controls Co. of America, Crystal Lake, Ill.

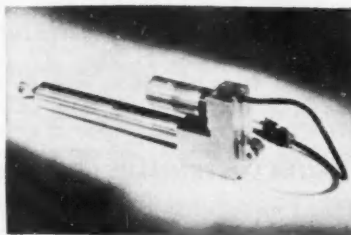
Circle No. 347 on reply card



TAKES SMALL STEPS

There are no mechanical ratchets on this thin, quiet stepper motor, which features a low radiated magnetic field. The Series 18100 motor does not need mechanical one-way devices, electrical contacts, or commutator. The motor may be operated with windings continuously energized in a static condition or pulsed at rates up to 2,400 steps per min. Minimum pulse requirements are 12.5 millisecc. Two units may be combined with a differential for bidirectional operation or algebraic addition. Series 18100 is rated at 27 vdc with a continuous duty cycle and a rotor step angle of 30 deg per cycle.—A. W. Haydon Co., Waterbury, Conn.

Circle No. 348 on reply card



HAS 6-IN. STROKE

This linear actuator uses a dc motor to provide 500 lb force over a 6-in. stroke via a precision ball screw. Standard rate of travel is 10 in. per min but



HIGH-PRESSURE FLOWS



BROOKS CAN METER THEM AS HIGH AS 100,000 PSII

Brooks rotameters work well under pressure. Right now there are several operating around the clock at 40,000 psi, in process lines ranging from 1/2 to 2 inches. Operation has been very satisfactory. Even on heavily pulsating flows. (The meters have built-in provision for pulsation damping. It is simple. And very effective.) ■ Brooks high-pressure meters can be supplied with either electric or pneumatic transmitting extensions. Both are compatible with most receiving instruments. Both use the Brooks magnetic position converter, the most reliable transducer of its kind. ■ If you have a high-pressure metering job, ask us about it. We can probably give you exactly what you need. And at a price somewhat lower than you'd expect to pay. Design Specification Sheet 3613 will give you more information.



BROOKS INSTRUMENT CO., INC.
5204 W. VINE ST. • HATFIELD • PENNSYLVANIA

Brooks Instrument Canada Limited, Scarborough, Canada • Brooks Instrument Company, S. A., Fribourg, Switzerland • Brooks Instrument Nederland, N. V., Veenendaal, Netherlands

SA 2360



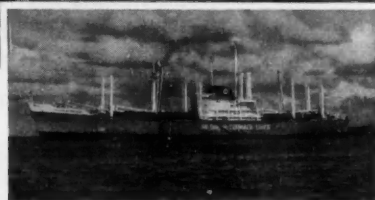
Seagoing recorder helps tame the tempest

To poet and pilot alike, the sea is unpredictable. But a long step toward fathoming its mysteries has recently been taken, in the form of an idea which will provide data on the effects of turbulent seas on ship motion. Among the benefits will be the design of hulls and ships better able to meet the challenges of wind and wave.

To help the U.S. Maritime Administration and the David Taylor Model Basin collect data for performing statistical analysis of ship motion, a "Seakeeping Instrumentation System" was designed by Sierra Research Corp. of Buffalo, N.Y. Operating completely unattended for periods of several weeks at a time, the system automatically goes into operation at 4-hour intervals, recording a short run if the weather is calm or a longer run if the weather is rough.

Heart of the system is a 14-channel P.I. instrumentation magnetic tape recorder, capturing such data as wind velocity and direction, ship's heading, roll and pitch, wave height, vertical acceleration, time pulses, and propeller shaft RPM and horsepower. The P.I. recorder was chosen for the system because of its superior reliability — no attention was required during its entire first cruise of four months — and because its compact design involves far less weight, space, and power than conventional recorders.

For details on other P.I. recorders used above and below the sea, check with your local Precision engineering representative or write direct.



S. S. MORMACPRIDE, which gathers data at sea through the automatic, unattended operation of the "Seakeeping Instrumentation System."



Clock, control unit, and recorder mounted in the Gyro Room of the Mormacpride's Bridge Deck.

P.I. invites inquiries from senior engineers seeking a challenging future.



PRECISION INSTRUMENT COMPANY

1011 Commercial Street • San Carlos • California
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REPRESENTATIVES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

188 CIRCLE 188 ON READER SERVICE CARD

NEW PRODUCTS

can be adjusted to meet other requirements. Maximum tension or compression load is 2,500 lb. Unit operates on 27-100 vdc (universal ac-dc operation available) in a temperature range from -65 to +300 deg F. Weight is 3 lb, 14 oz; unit measures 14 $\frac{1}{8}$ in. long by 1 $\frac{1}{2}$ in. wide by 3 $\frac{1}{2}$ in.—Globe Industries, Inc., Dayton, Ohio.

Circle No. 349 on reply card

COMPONENT PARTS



REFERENCE JUNCTION

Designed to provide a temperature reference for multichannel thermocouple systems, this junction operates on 105-125 volts, 380-420 cps. Operating temperatures range from -65 to +165 deg F with less than $\frac{1}{4}$ deg reference temperature variation. Accuracy is claimed to be better than that attainable with ice baths, mechanically thermostated enclosures, or cold junction compensators. Units are available with up to 24 channels and any junction temperature from 25 deg F above ambient to 250 deg F. Temperature uniformity and stability for long term unattended operation are within $\pm\frac{1}{4}$ deg F. Unit weighs 2 lb. Price for 24-channel junction: \$540.—Pace Engineering Co., No. Hollywood, Calif.

Circle No. 350 on reply card

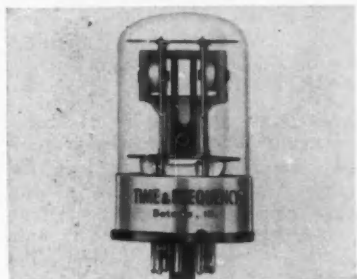
MAGNETOSTRICTIVE DELAYS

Delays up to 5,000 microsec with an adjustment of 5 microsec are available with this Model 2370 magnetostrictive delay line. The device is designed to operate in an ambient temperature range of -55 to +70 deg C. Temperature coefficient is less than 20 ppm/-deg C; 4 ppm/deg C can also be sup-

CONTROL ENGINEERING

plied. Insertion loss is approximately 60 db, and signal to noise ratio is better than 10 to 1. Carrier frequency ranges from 250 kcps to 1 Mcps. A low price is featured.—Power-Tronic Systems, Inc., New Rochelle, N.Y.

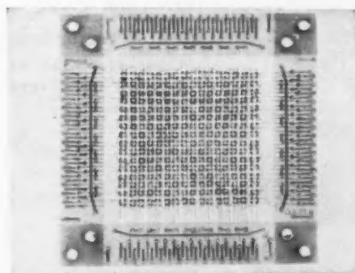
Circle No. 351 on reply card



VACUUM TUNING FORK

This Type TF-4 tuning fork provides an accurate frequency source for electronic instruments. Enclosed in a high vacuum glass tube, the device is 1½ in. in diam and 2½ in. high with an octal socket. The tuning fork, with silicon transistor oscillator, will operate from 240 to 10,000 cps. Ovens or other complex thermal controls are said to be unnecessary because of the tube's accuracy. Output signal is either sine or square wave of 1.3 to 3.0 volts rms across a 10,000 ohm load. Power supply needed is 6-36 vdc with a current drain of less than 10 ma. The device is unaffected by gamma rays or fast neutrons. Price: \$135.—Time & Frequency, Batavia, Ill.

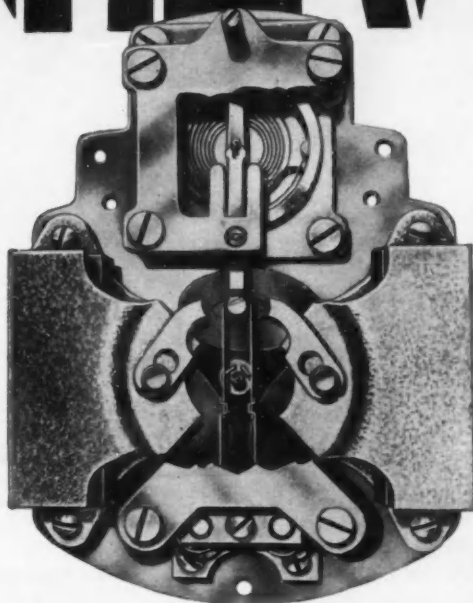
Circle No. 352 on reply card



MEMORY FRAMES

Four sizes of these printed circuit strip memory frames are available for use in memory systems of business machines. There are 10 different frame configurations, and any of several types of 50-mil and 80-mil ferrite cores can be used. Base material can be glass epoxy, paper phenolic, or other material. Solder plated circuitry is incorporated in all standard strips, though other plating materials are available. Price for 32 x 32 array is \$60 to \$70.—

NEW



This cutaway view shows a 150 rpm governed motor that runs for more than a year on a single "D" flashlight battery. Originally developed by The A. W. Haydon Company to drive a cordless electric clock, its 1.5V motor winding keeps accurate time (± 10 seconds over 24 hours... or an accuracy of 1/50 of 1%) over a voltage range from 0.9V to 1.8V. In its first application, this constant-speed DC motor was used in a chart drive having a timing cycle of 192 hours. Withal, a fine example of the A. W. Haydon Company's high capability in timing devices, be they electrical or electronic.

WHO'S FOR A REALLY NEW TIMING DEVICE

So new, that A.W.Haydon Co. has found only one customer for it...so far!

Do you have an application requiring a DC motor having extremely low current consumption, very high accuracy, and long life at constant speed? If so, you should know more about this new chronometrically governed motor: windings for nominal voltages from .5V to 12V within the same motor frame are available...weight is only 3 oz., even when enclosed in a 2½" x 1¼" x ½" plastic dust cover...and there is a convenient means for adjusting regulation. An appropriate gear train can also be fitted. Write for any other specifics you feel you would like to know about.



THE A.W. HAYDON COMPANY

246 North Elm Street, Waterbury 20, Connecticut

THE ONE TIMER WITH ALL THE FEATURES...



Only in a STANDARD instrument do you get all the features "most wanted" in an interval timer:

UNEXCELLED PRECISION—Consistent, continuous accuracy over years of use. Accuracy to $\pm .001$ second available in standard models.

INSTANTANEOUS ELECTRIC RESET—A "must" in many instrument complexes—a plus benefit for all other applications.

PROVEN MECHANISM—Synchronous motor driven—electric clutch operated. Proved reliably accurate and dependable by years of service.

CHOICE OF CONTROL—Start, stop and reset can be manual, by electric circuit or output of electronic tubes.

RANGE OF MODELS—Portable or panel mounting—in a wide selection of accuracies and ranges.

Request Catalog No. 198-B



**THE STANDARD ELECTRIC
TIME COMPANY**
89 LOGAN ST., SPRINGFIELD, MASS.

NEW PRODUCTS

Lockheed Electronics Co., Avionics and Industrial Products Div., Los Angeles, Calif.

Circle No. 353 on reply card

LOGIC SIMPLIFIER

Types 2N892 through 2N901 Triggers in the TO-18 package now available offer simplification in logic circuitry. With complete on-off control at a single base input, binary functions can be accomplished with only one active element per stage; the number of auxiliary components is also reduced. The 2N2892 series has ratings to 200 volts and extremely high sensitivity: inputs of the micro-ampere level. The silicon PNP products are priced from \$10.50 each in small quantities.—Solid State Products, Inc., Salem, Mass.

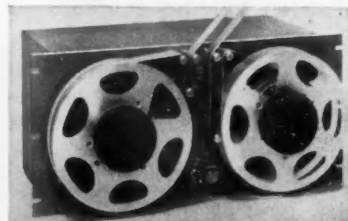
Circle No. 354 on reply card

PLUS . . .

(355) Foster & Allen, Inc., Chatham, N.J., has introduced a Versa Gear quick change gear chassis which makes possible a great range of ratios by simple changes of instrument gears on sliding bearing blocks. . . . (356) Standardized packaged slip ring assemblies for instrumentation circuits, available from Superior Carbon Products, Inc., Cleveland, Ohio, accommodate 15-30 rings and allow low cost because of large quantity production.

Circle Nos. 355 or 356 on reply card

ACCESSORIES & MATERIALS

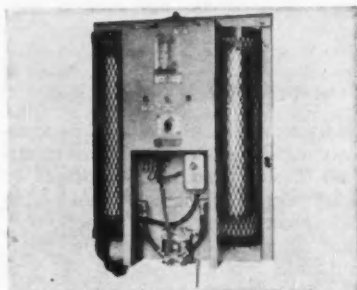


WINDS TAPE

This bidirectional automatic tape spooler may be used with any tape

reader to wind paper or Mylar tape on standard NAB reels up to 8 in. in diam. A total of 1,000 ft may be wound at a speed of 15 ips. Winding is controlled by a tension arm that senses slack in the tape. No external control signal is needed for operation. The TS-400 is made to take up 8½ in. in a standard 19-in. rack. Price: \$495.—Electronic Engineering Co. of California, Santa Ana, Calif.

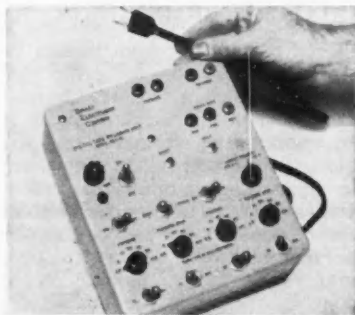
Circle No. 357 on reply card



DRIES INSTRUMENT AIR

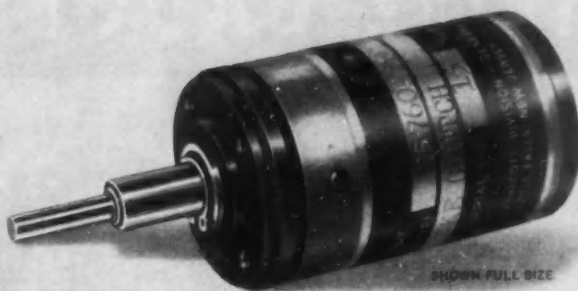
Desiccant-type dehydrator systems, like the one shown above, are said to be the most effective and economical ways of removing moisture from instrument air. This air dryer has a minimum of valves and solenoids for easy operation and maintenance. The unit is completely automatic and is designed for wall mounting. Flow capacities from 0.5 to 10 cfm are available. In operation one tower is dried while the other tower dries instrument air with only seconds needed to change the air flow from one tower to the other. Price: approximately \$239.—S & G Manufacturing Corp., New Orleans, La.

Circle No. 358 on reply card



COMPACT PROGRAMMER

Automatic control of digital tape machines is possible with this small tape program unit. Forward and reverse run times are individually adjustable in the range from 2.5 millisecon to 1 sec by means of selector switches. The programmer can be used for off line



MINIATURE, HIGH PERFORMANCE MAGNETIC BRAKES AND CLUTCHES

Typical applications involving these Size 11 magnetic clutches, brake clutches, and brakes include service as output controls in mechanical differential computers, as motor brakes, and as speed changers and uncouplers. Kearfott can also provide magnetic clutches, brake clutches and brakes in various other sizes to suit desired applications. Components also available in sizes 8 and 6 diameters.

CHARACTERISTICS

Unit No. Size	Magnetic Clutches		Magnetic Brake Clutch	Magnetic Brake
	R5750-001	R5750-002	R5760-001	R5770-001
Power input (Watts)	3	3	3	3
Clutch Torque (In. Oz.)	6 (energized)		4 (energized)	—
Brake Torque (In. Oz.)	—	—	6 (de-energized)	16 (energized)
Inertia (gm cm ²)	.82 (energized)	.56 (de-energized)	.82 (energized)	.56 (de-energized)
Engaging Surfaces	Steel	Brake Material	Steel and Brake Material	Steel
Environmental Performance	Per MIL-E-5272A			
Life (Cycles)*	3,000,000			

*1 Cycle=1 revolution of shaft engaged and 1 revolution of shaft disengaged, at 500 RPM.

Write for complete data



**KEARFOTT DIVISION
GENERAL PRECISION, INC.**

Little Falls, New Jersey

HEISE GAUGES

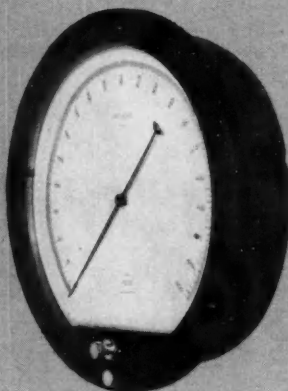
Test Standard ACCURACY

Only Heise gauge guarantees accuracy to 0.1 of 1% full scale reading at all points on a fully graduated 270° dial.

In laboratories throughout the world, the Heise gauge is being used as a test reference for recalibration of other instruments and testing of critical components.

All Heise gauges maintain the same standard of accuracy and are available in ranges from 0 to 15 p.s.i. to 0 to 100,000 p.s.i. Hysteresis, regardless of pressure range, is held within the same 0.1 of 1%.

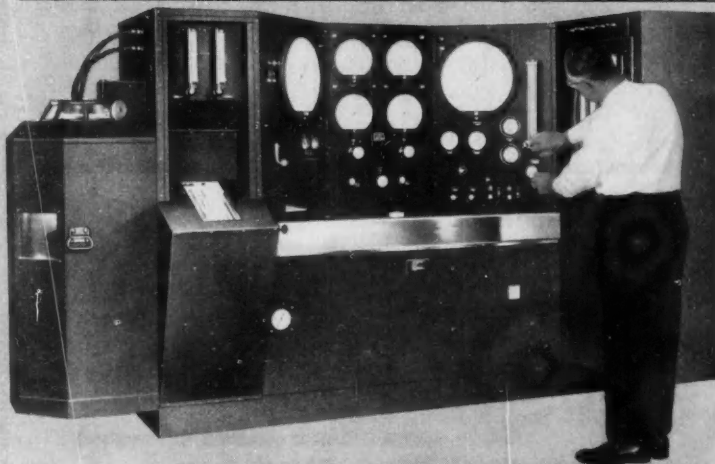
The Heise laboratories, specialists in Bourdon tube equipment since 1930, have developed and perfected this instrument which stands alone in the field as a secondary standard approached only by the primary dead weight tester.



ACCURACY
0.1 of 1%

HYSTERESIS
0.1 of 1%

CAPACITY
0-100,000 p.s.i.



Dial Sizes	FULL SCALE READING (P.S.I.)						
	0-15 to 0-5,000 inclusive	Over 0-5,000 and including 0-20,000	Over 0-20,000 and including 0-30,000	0 to 40,000	0 to 50,000	0 to 75,000	0 to 100,000
8 1/2"	\$183.50	\$205.50	\$238.50				
12"	\$209.50	\$231.50	\$264.50	\$275.50	\$286.50	\$336.50	\$386.50
16"	\$255.50	\$277.50	\$310.50	\$321.50	\$332.50	\$382.50	\$432.50
DELIVERY — 2 WEEKS FOR MOST RANGES — PRICE F.O.B. NEWTOWN							

DELIVERY — 2 WEEKS FOR MOST RANGES — PRICE F.O.B. NEWTOWN

Request Catalog for SPECIAL FEATURES

HEISE BOURDON TUBE COMPANY, INC.
BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

NEW PRODUCTS

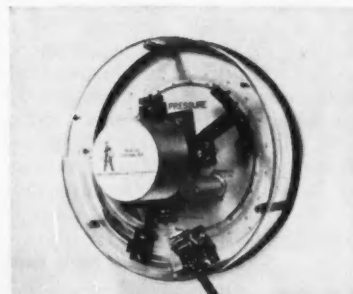
control of digital tape machines to aid in servicing and adjustments. The unit generates forward and reverse outputs which drive the actuator control circuits of the tape machine. Size of the programmer is approximately 4 x 7 x 8 in. Price: \$450.—Binary Electronics Co., Fullerton, Calif.

Circle No. 359 on reply card

FOR TEMPERATURES

Supramica 620 BB is a high performance ceramoplastic that offers insulation capabilities at temperatures to 1,200 deg F, along with moldability to intricate shapes and hermetic sealing. Dielectric strength is 270 volts/-mil, and arc resistance is 300 sec. Volume resistivity at 932 deg F is 10^8 ohm-cm. Helium leakage rate is on the order of 10^{-10} cu cm per sec after severe environmental tests.—Mycalex Corp of America, Clifton, N.J.

Circle No. 360 on reply card



CONVERTS READINGS

Digital data output from pointer instruments is possible using this converter in which a scanner attaches—using adapters—to the instrument to be read, and an electronics unit displays the digital readout. Input can be to any digital printer or card or tape punch. The scanner (shown above) translates the pointer's angular position, relative to a reference point, into a pulse time interval. This is done by measuring the interval between two pulses generated by a momentary contactor and a photoelectric pickoff. Display is by digital readout tubes at a rate of 36 per min. Typical resolution is 1 part in 1,000; typical accuracy: within 10 percent ± 1 count.—MacLeod Instrument Corp., Ft. Lauderdale, Fla.

Circle No. 361 on reply card

BULLETINS AND CATALOGS

(400) **COMPLETE CONTROLLER LINE.** Minneapolis-Honeywell Regulator Co., Industrial Div. Catalog C-15-2a, 56 pp. Covers complete line of the manufacturer's Electronik controllers, including pneumatic and electric versions. Basic circuits are given as well as complete specifications and detail photographs on the many units in this controller line. Also included are partial chart listings and contact control forms.

(401) **BACKWARD DIODE GUIDE.** Hoffman Electronics Corp., Semiconductor Div. Handbook, 48 pp. Short form booklet goes back in time to describe characteristics of the unitunnel or backward diode. Humorous pictures and captions complement useful technical discussion of physical and electrical parameters, testing criteria, and typical circuit applications.

(402) **NUCLEAR RADIATION EFFECTS.** General Electric Co., Receiving Tube Dept. Bulletin ETD 2564, 22 pp. Brightly laid out booklet reviews effects of pulse and steady state radiation on various types of circuits and components. Comparative data are used to show advantages of Thermionic Integrated Micro Module (TIMM) circuits in the presence of damaging radiation sources.

(403) **SIZING GUIDE.** Aeroquip Corp. Bulletin No. 631, 16 pp. Discusses various fittings to show how to design fluid line installations. Clear drawings and charts are used to show how to measure pipe, tubing, and hose.

(404) **ADJUSTABLE SPEED COMPONENTS.** The Louis Allis Co. Bulletin 2900, 6 pp. Cutaway illustrations and specification chart are used to describe complete packaged adjustable speed drives. In addition, details are given on associated control components. Four types of drives described include ac and dc drives, liquid cooled mechanical drives, and ac motor driven mechanical types.

(405) **ROTARY SWITCH CATALOG.** The Daven Co., Sub. of General Mills, Inc. Catalog, 48 pp. Well illustrated publication uses large size photographs, dimension drawings, and specification tables to describe complete line of rotary switches. An introductory section details materials used and characteristics of the switches along with typical applications. The company's "shorthand" method of ordering is also given.

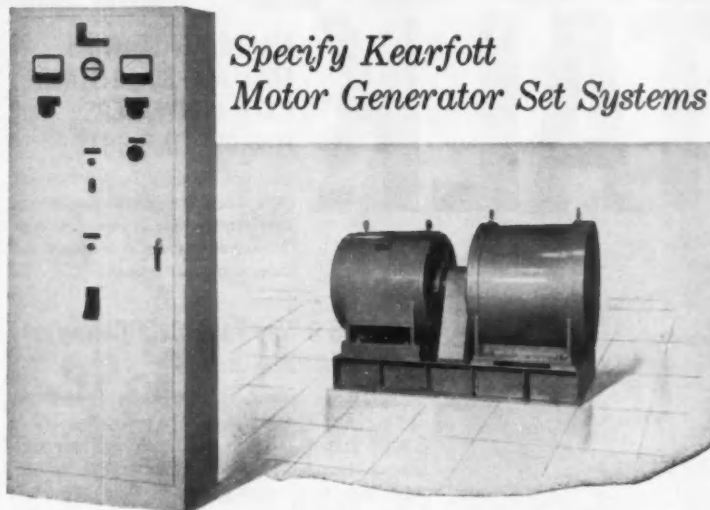
(406) **EASY ORDER TRANSDUCERS.** Advanced Dynamics, Inc. Catalog, 60 pp. A format designed for simple ordering of this manufacturer's line of thermocouples, pressure probes, and allied components is used in this catalog, which contains specifications, construction details, and prices.

(407) **VARIED COMPONENTS LINE.** Minarik Electric Co. Catalog. This ring-bound volume containing several hundred pages gives engineering information including dimensions, etc., for small electro-mechanical drive systems, timing devices, variable speed controls, speed reducers, and electric motors.

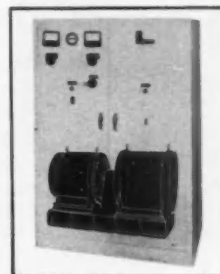
(408) **THEORY AND APPLICATIONS MANUAL.** General Electric Co., Power Tube Dept. Bulletin PT-49, 20 pp. De-

FOR PRECISE 400-CYCLE POWER

*Specify Kearfott
Motor Generator Set Systems*



Kearfott 60-to-400 cycle motor generator frequency converters are in active use wherever precise 400-cycle power must be supplied . . . including laboratories and in such other representative applications as production testing, high speed tool operation and ground support. These generator systems, which consist of a 60 cycle synchronous motor and a 400 cycle generator, can be supplied with controls and generator as an integral, compact unit—or with controls and generator separately located.



PERFORMANCE SPECIFICATIONS

Frequency: 400 cycles under any rated load condition with 60 cycle input.

Voltage Regulation: Within $\pm 1\%$ of rated voltage when (1) load varies between no-load and 125% of rated load, and/or (2) load power factor varies between 0.8 lagging and unity, and/or (3) equipment temperature varies after approximately 10 minutes' operation.

Voltage Recovery: When rated load is suddenly applied or removed, voltage will return to and remain within regulating band within 0.25 seconds.

Voltage Adjustment: Continuously adjustable to $\pm 10\%$ of rated value.

Deviation Factor: Maximum 4% between no load and full load.

Overload: Equipment delivers 125% of rated load for 2 hours.

Amplitude Modulation: Maximum 1% of peak-to-peak voltage at any load between no load and full load, at any power factor between 0.8 lagging and unity.

Frequency Modulation: Maximum 0.5% at any load from no load to 125% of rated load.

Write for complete data



**KEARFOTT DIVISION
GENERAL PRECISION, INC.**

Little Falls, New Jersey

Sales and Engineering Offices: 1500 Main Ave., Clifton, N. J.
Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
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DOUBLE TALK

MAKES SENSE WITH EECo ALL SOLID-STATE DATA CONVERTERS FOR OFF-LINE DUTY

One data language in. Another out. Fast, accurate performance and long service life, at new, low cost. Off-line operation to conserve valuable computer time.



EECo-753 3-Way Tape Data Converter

for business or scientific use

• Paper-to-Magnetic Tape • Magnetic-to-Paper Tape • Paper-to-Paper Tape—5-, 6-, 7-, or 8-level paper tape in any coding in or out. IBM 704 or IBM 705 magnetic tape in or out. Selectable block lengths up to 720 characters stored in ferrite core memory. Manual-visual check of code conversion and memory.

PRICE \$62,500 fob Santa Ana

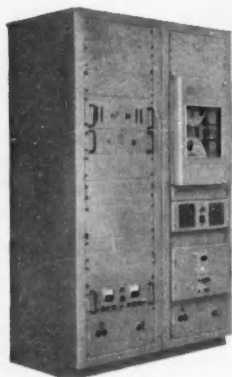


EECo-752 Data Converter

for business or scientific use

Converts 5-level Teletype paper tape to magnetic tape for IBM 704 or IBM 705. Manual-visual check of code conversion and memory. 128-character ferrite core memory.

PRICE \$36,500



EECo-751 Format Control Buffer

for scientific use

For entry into IBM 650, IBM 704, IBM 705, IBM 709. Or can be furnished for other computers. Accepts digitized data in parallel form at random rates.

PRICE \$38,500-\$45,000

SEND FOR DATA FILE 751-3. All converters employ Engineered Electronics Co.'s all-solid-state plug-in circuits throughout.



Electronic Engineering Company of California

1601 E. Chestnut Avenue • Santa Ana, California • Kimberly 7-5501 • TWX: S Ana 5263
MISSILE & AIRCRAFT RANGE INSTRUMENTATION • DIGITAL DATA PROCESSING SYSTEMS • TIMING SYSTEMS •
COMPUTER LANGUAGE TRANSLATORS • PAPER TAPE PROGRAMMERS

EE 0-10

Bulletins & Catalogs

scribed as the only source book for this class of tubes available to equipment designers, bulletin gives complete background information on hydrogen thyratrons. Specific references are made to three different tubes for data and ratings. Schematics, graphs, and charts are employed to cover construction, operation, applications, and characteristics of the tubes.

(409) GP LAB SCOPES. Tektronix, Inc. Booklet, 20 pp. Eight available complete-unit oscilloscopes are described in this catalog-style publication. Specifications, performance characteristics, and illustrations for single beam, dual beam, dual trace, and rack mounting models are given. Four models for dc to 450 kcps, one for dc to 1 Mcps, and three for dc to 15 Mcps are included.

(410) RESISTOR NETWORK DESIGN. General Resistance, Inc. Design form. Originally developed for the company's internal use, this form saves engineering time in specifying resistor networks. Form consists of 25 x 11 in. sheet folded into three letter-sized parts.

(411) PASSIVE MICROWAVE REPEATERS. Microflex Co., Inc. Manual No. 161, 48 pp. A wealth of highly specialized information on the use of passive repeaters in microwave systems is given in this profusely illustrated manual. Complete specifications on the company's line of such repeaters are given along with simple calculations to illustrate the technical background given in the publication. Repeaters are available for applications from 2,000 to 12,000 Mcps.

(412) RELIABILITY IN ACTION. Hoffman Electronics Corp. Bulletin, 28 pp. Well laid out publication describes company's experience in complying with AGREE (Advisory Group on the Reliability of Electronic Equipment) in its production of TACAN equipment. Describes new concepts, techniques, and thinking that went into the project. Diagrams of AGREE procedures are included. (413) LIMIT SWITCH GUIDE. General Electric Co. Bulletin GEA-7312, 12 pp. Describes company's line of limit switches for automatic pilot control. Also includes a glossary of limit switch terminology and well illustrated guide to installation procedures. Types of limit switches included are lever, leverless, and rotating cam.

(414) PLASTICS PROPERTIES. Cadillac Plastic & Chemical Co. Table. Significant physical, electrical, mechanical, and optical properties of nine different thermoplastic materials are given in this chart assembled from test reports submitted by the manufacturer. A total of 35 different properties are tabulated. Reverse side of chart contains square inch to square foot conversion table.

(415) APPLICATION CASE HISTORIES. Gilmore Industries, Inc. Bulletin TD-105, 48 pp. Contains a series of articles on different applications of high accuracy transducer systems. Applications range from electronic weigh loading of hot material to strain gage testing of aircraft and submarines.

(416) CIRCUIT DESIGN AID. Amperex Electronic Corp. Guide and Booklet,

6 pp. Computa-Guide is the name of this graphic aid designed to save engineers' time in calculating harmonic components of complex wave forms. Guide is printed on plastic laminated card, and booklet contains detailed illustrated instructions for its use with hints for using the guide to full advantage.

(417) **SERVOTEST INSTRUMENTATION.** Industrial Measurements Corp., c/o John Jones Co., Inc. Brochure, 20 pp. Four-section publication contains data sheets on instrumentation designed for static and dynamic evaluation of electrohydraulic servovalves and servosystem actuators. Included are illustrated descriptions of valve flow analyzers, dynamic response analyzers, metering cylinder assemblies, and other equipment.

(418) **SPACE AGE SILICONES.** General Electric Co. Silicone Products Dept. Brochure CDS-276, 16 pp. Provides general background on silicone products for use in a variety of applications. Included are descriptions of silicone insulation; varnishes; encapsulating materials; and dielectric fluids, coolants, and greases.

(419) **MEASURING DEVICES.** United Sensor & Control Corp. Catalog 61, 40 pp. Line of flow probes, thermocouples, and positioners for measuring velocity, temperature, and flow of gases and liquids are described in this publication. It also gives complete technical information on their use. Serves as a simple text book for fluid flow measurement.

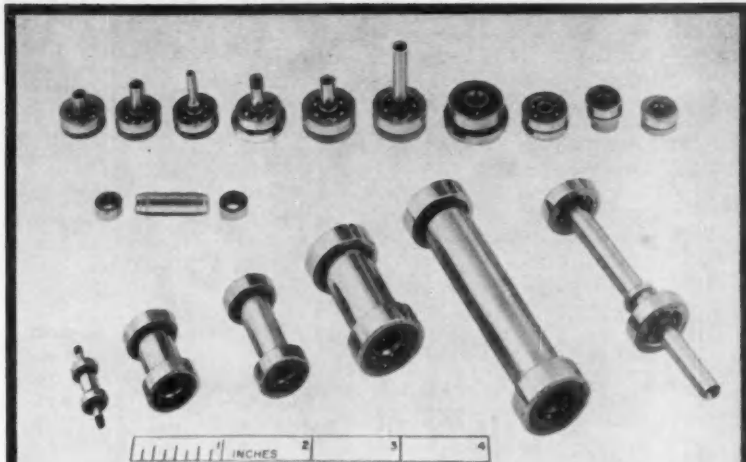
(420) **COMBUSTION CONTROL SELECTION.** Reliance Instrument Div., Electro-Mech Corp. Bulletin 1001, 32 pp. Presents clear analysis of the two main types of combustion control systems: proportioning and metering. Using block diagrams, the publication describes the systems, pointing out specific advantages and serving as a guide for system selection.

(421) **DIGITAL COMPONENTS.** Ransom Research, Inc. Catalog, 24 pp. Contains 11 data sheets on computer elements including counters, NOR logic elements, flip-flops, power regulators, and analog to digital converters, among others. Photographs and schematic drawings complement full technical description of each device. Also included is a complete price list.

(422) **UNIUNCTION PACKAGE.** General Electric Co., Electronic Components Div. Semiconductor Products Dept. Design package. Contains several data sheets, a price list, technical background, reliability information, and test results for the 2N-1671 unijunction transistor series. Lower prices are also announced.

(423) **MICROWAVE RELAYS.** GPL Div., General Precision, Inc. Brochure. Describes the 420A microwave relay, a 0.1-watt, 5-Mcps bandwidth system operating in the 10,500-13,200 Mcps frequency range for point-to-point transmission of various signals including data channels. Small size and low cost are features of the equipment.

(424) **DATA TRANSMISSION SYSTEM.** Digitronics Corp. Brochure, 6 pp. Describes recently introduced Dial-o-verter system, which functions with the Bell System Data-phone 200 to send and receive data at high speed to and from a number of remote locations over regular telephone or private lines. Photographs of the equip-



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ment and explanation of the features of the system are included.

(425) **FOUR-LAYER DIODE CATALOG.** Shockley Transistor, Unit of Clevite Transistor. Catalog, 6 pp. Tables of electrical specifications and dimension drawings along with a brief description tell the story of this company's line of these four-layer diodes, a two-lead silicon switch.

(426) **TRANSFORMER PRODUCTS.** Dresser Electronics, HST Div. Catalog No. 103, 26 pp. Features nearly 300 transformers, chokes, and reactors available off the shelf. Time saving catalog format uses quick reference index to guide users to detailed tables and graphs of engineering data. Photographs and prices for the units are also given.

(427) **BATCH CONTROL.** Electronics Div., Fairbanks-Morse & Co. Brochure, 4 pp. Covers the Batchetron 600 automatic batching control system specially designed for concrete and asphalt proportioning. System uses load cells to weigh out preset amounts of material. Publication's illustrations simplify understanding of the system.

(428) **ELECTROMECHANICAL POSITIONERS.** Hanna Engineering Works. Bulletin 500A, 10 pp. Liberally illustrated bulletin shows how to use the company's Hanna-Powr positioners to position many types of mechanical devices automatically. Flow action illustrations, line drawings, and charts are used to give specific application information.

(429) **HANDBOOK-CATALOG.** Superior Instrument & Manufacturing Corp. Catalog 600-1, 28 pp. Publication is a combined technical handbook and catalog covering the manufacturer's line of gear-head and speed reducers. Four sections cover general technical data, complete specifications on the components, packaged servomechanisms, and firm's facilities.

(430) **TRANSISTOR SPEC SHEETS.** Sperry Semiconductor Div., Sperry Rand Corp. Specification sheets, Three sheets (two 4 pages each and one 2 pages) describe the 2N1917 through 2N1922 series of PNP, alloy junction transistors designed for high level chopper and electronic commutating applications. Electrical data, ratings, suggested applications, and graphs of emitter characteristics are included.

(431) **VARIABLE SPEED DRIVES.** Reliance Electric & Engineering Co. Catalog G-100, 88 pp. Covers complete line of drives from $\frac{1}{4}$ through 40 hp. Included are selection and ordering information, cut-away drawings, and complete specifications with photos of drives and accessories.

(432) **TRANSISTORIZED POWER.** Victory Electronics, Inc. Brochure, 8 pp. Describes complete line of regulated transistorized power supplies, frequency changers, and converters for use with equipment such as infrared detectors.

(433) **NUCLEAR INSTRUMENTATION.** Hamner Electronics Co., Inc. Catalog, 40 pp. Illustrated publication describes nuclear instruments and systems designed for counting or analyzing. Catalog gives complete technical specifications and furnishes valuable application aids.

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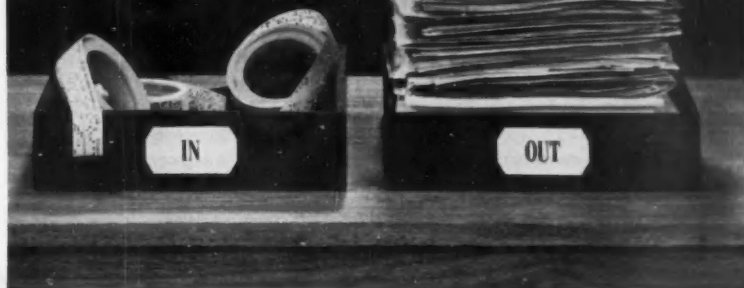
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APRIL 1961

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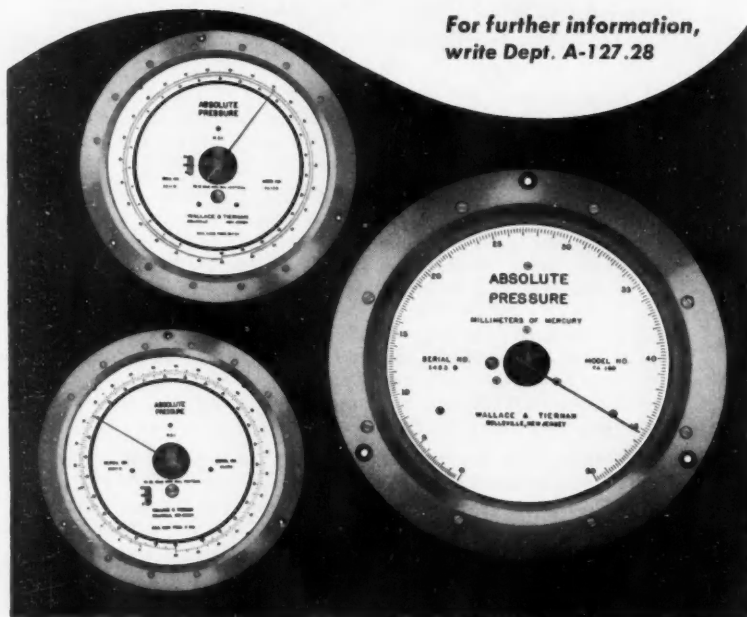
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WHAT'S NEW

(Continued from page 48)

reason, the bins can overflow and the extra letters are almost sure to be ripped and torn by the machinery.

One solution that has been proposed is to install pressure operated warning lights that would indicate when the bin needed emptying. Another suggestion is to incorporate an automatic dumping mechanism.

Another difficulty has been mail "piggybacking" at the cullers where the letter mail is automatically separated from odd-sized mail. The letter mail is supposed to drop through a slot to be carried to the semi automatic sorter. But some of it rides on top of other pieces and does not drop onto the conveyor. And mail that has been tied in packages by the sender—something the Post Office Dept. encourages—can't be culled.

• **No time for schedules**—Many of the problems that are now plaguing the modern post office can be blamed on the rush with which the facility was put into operation. Construction was started April 1, 1959; the building was dedicated on October 20, 1960; but it wasn't until December that postal employees could move in.

Startup of the mechanized operation synchronized almost exactly with the beginning of the Christmas mail rush. Faced with the decision of hiring more space or using the Turnkey facility, the department decided to try the new system. As a result the debugging procedure started while the system was trying to handle almost 3 million pieces of mail a day—about twice the design load.

Despite the heavy criticism, most people C&E interviewed were confident that Project Turnkey would eventually operate successfully and make a significant contribution to the modernization of mail handling. But the troubles, magnified by the political atmosphere, spotlight some frequently neglected aspects of systems engineering.

Indian Instrument Need Set To Double, Says Commerce

Demand for instruments in India is expected to double by 1965-66 from its present rate of \$37.8 million, according to a report issued by Nathan D. Golden, director of the Scientific, Motion Picture, and Photographic Products Div. of the Dept. of Commerce. The forecast was based on a dispatch from the American embassy in India.

The embassy's report noted that imports would continue to supply the major portion of Indian instrument

needs, despite the progress being made by domestic manufacturers. Principal suppliers to India are England, West Germany, and the U.S. In fact, India is one of the 15 best markets for U.S.-made instruments, with sales in the past five years ranging from \$2.5 to \$4 million.

Production of instruments by Indian companies was estimated at \$6.3 million worth in 1959, but of this only 18 percent was in industrial process and control goods. About half the output was scientific instruments for teaching; the rest included surveying and other teaching instruments.

A possible thorn in the side of Western efforts to sell instruments in the growing Indian market, it should be noted, is Russia's substantial economic and technical assistance there. The Soviets have been building plants for the Indian government, and there is a good possibility of inroads by Russian instrument suppliers.

News of Companies in the Control Field

MITE Corp. has been formed in New Haven, Conn., out of the merger of the 89 year old Greist Manufacturing Co., also of New Haven, with Teleprinter Corp., Paramus, N.J. The initials stand for Miniature Industrial Technical Equipment.

Fairchild Camera and Instrument Corp., Syosset, N. Y., has purchased the flight data recorder business of Waste King Corp. in Los Angeles. Other instruments were also included.

Magnetic Controls Co. and **ADC, Inc.** of Minneapolis, Minn., will merge, with the former company being the surviving partner. The plan must be approved by state and Federal agencies and by stockholders.

Amphenol-Borg Electronics Corp., Broadview, Ill., and **FXR, Inc.** of Woodside, N.Y., have agreed in principle to a plan for merger. All outstanding obligations of FXR would become obligations of Amphenol.

International Computers and Tabulators Ltd. has formed a new subsidiary, **ICT (Engineering) Ltd.**, which will absorb the ICT Research and Design Div. and the Computer Development Dept. of General Electric Co. Ltd. GEC will keep 10-percent interest in the English firm.

Dashew Business Machines, Inc. of Los Angeles has added **Universal Data Processing Equipment, Inc.** as an autonomous subsidiary.

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... ACCURATE METERING WITH SMOOTH CONTROL

Wallace & Tiernan's newest plunger pump delivers 3.2 gph vs 1200 psi to 50 gph vs 100 psi, repeatable within $\pm 1\%$. Easy adjustment over 10:1 range with the pump running.

... DOUBLE CAPACITY OR TWO-LIQUID METERING

A second liquid end doubles capacity or gives simultaneous feeding of two liquids. Stroke length for each end individually adjusted.

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Unitized construction means the Series 100 Pump stays in perfect alignment. Wear and maintenance are held to a minimum. Corrosion-resistant wetted parts handle most chemicals. The Series 100 Pump, with motor, is compact. With two liquid ends it occupies less than 2 sq. ft.

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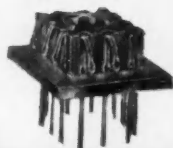
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Keith Heads IBM's Service Bureau Corp.

New president and director of International Business Machine Corp.'s subsidiary, The Service Bureau Corp., is Herbert R. Keith. Keith had been director of marketing services for the parent company before accepting the post with the contract data processing unit.

Vacancy in the Service Bureau's top post was caused by the appointment of its former head, Frank T. Clary, to an unidentified newly created post in the IBM corporation organization.

Keith joined IBM in 1933 as a sales representative and has served in various sales managerial posts. In addition, he has been assistant director of product planning and market analysis for the New York based firm and has also been executive assistant to the executive vice-president.



George Krsek Takes High Post at International Rectifier



New executive vice-president and general manager of International Rectifier Corp., El Segundo, Calif., is George Krsek, an experienced semiconductor chemist, research director, and production executive. Krsek joins the firm after 13 years at Merck and Co., Inc., a New Jersey pharmaceutical manufacturer, where for the past four years he had served as director of that company's Electronic Chemicals Div., which produces silicon, germanium, and other semiconductors. He originally developed synthetic cortisone.

In his post at International Rectifier, Krsek will be responsible for research and development, engineering, purchasing, manufacturing, and sales for the company.

Naish Leaves Convair; Widespread Changes Hinted

J. V. Naish, 53-year-old president of Convair Div. of General Dynamics Corp. and senior vice-president of GD,

has resigned because of "amicable but irreconcilable differences in management philosophy". C. Rhoades MacBride, a GD executive vice-president, has been named acting president by board chairman Frank Pace, Jr.

Naish has not announced his plans for the future. He had been Convair president since 1958 and executive vice-president for five years before.

If Naish's future is undecided, so seems Convair's. The San Diego based GD division (since 1954) is one of the largest missile and aircraft manufacturers in the nation. It was believed that other Convair top brass, including August Esenwein, executive vice-president, would also resign. Unidentified company spokesmen said that McBride's appointment was probably temporary.

These sources also mentioned the possibility of one of two major reorganization plans. One would be the elimination of the Convair general office here and direct operation of the outfit by the GD corporate staff in New York. Another plan might see a corporate realignment to put Convair-San Diego and Convair-Ft. Worth into one division, Convair-Pomona into another, and Convair-Astronautics (in San Diego) into a third. This would have the effect of emphasizing missile work.

The Ft. Worth and San Diego groups are engaged in commercial and military aircraft manufacture. Pomona is a testing and instrumentation setup. It might be affected by GD's plan to combine the electronics groups in other divisions with the Stromberg-Carlson Div. to form GD/Electronics (CtE, Mar. '61, p. 202). Astronautics is the missile and space vehicle unit of Convair's operations.

GPL Names Three to Top Engineering Positions

John C. Forrest (photo) heads the trio of new engineering appointments at GPL Div., General Precision, Inc.; he has been named director of the Pleasantville, N. Y., division's Engineering Div. Also announced were the appointments of Frank N. Gillette as associate director of that division and Louis L. Pourciau as head of the Industrial Products Dept.

Forrest has been with GPL since



1955; previously he was chief engineer for Radar and Special Products. Gillette was chief engineer for Industrial Products and was among the original group of scientists who joined GPL in 1946. Pourciau also came to GPL in 1946; his most recent post was head of the Electronic Dept. in Industrial Products.

Sailer Appointed At Diehl Manufacturing

Norris H. Sailer, who developed Singer Manufacturing Co.'s numerical control system, has been appointed Numerical Control Dept. manager at Diehl Manufacturing Co., Singer's subsidiary in Findern, N. J., now producing the control.

Sailer has been with Singer for 14 years. He initiated the control project 30 months ago as an outgrowth of cost reduction studies of short-run quantity production in the Diehl manufacturing plant.

Other Important Moves

Robert R. Beachler, Jr., is the new vice-president of Leach Corp., Los Angeles. He has been director of engineering for the corporation for the past three years. He will also be general manager of the Leach Relay Div.

Ralph L. Shapcott is now director of manufacturing and assistant general manager of the Weston Instruments Div. of Daystrom, Inc., in Poughkeepsie, N. Y. Prior to joining Daystrom a year ago, he was general manager of the Industrial Instruments Div. of Fischer & Porter Co.

T. H. Abrahams has been appointed chief engineer of the Instrument Div. of Hoffman Electronics Corp. in Los Angeles. The division was formed earlier this year (CtE, Mar. '61, p. 203). Prior to joining Hoffman, Abrahams spent nearly five years at Douglas Aircraft Co.

Eric J. Isbister is vice-president of engineering for Radiation, Inc. in Melbourne, Fla. Formerly Isbister was chief engineer of Sperry Gyroscopic's Surface Armament Div.

John D. Goodell is the new president and general manager of USI Robodyne Div. of U.S. Industries, Inc. He was previously director of engineering of the Silver Spring, Md., firm. Also in the U.S. Industries organization, Robert E. Root is now vice-president for training systems for Western Design & Electronics Div. in Santa Barbara, Calif. He'll be re-



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WHAT'S NEW

sponsible for all activities of the Training Systems Dept. which include the firm's line of AutoTutor automatic teaching machines.

Antonio Ferri has been elected president of General Applied Science Laboratories, Inc. of Westbury, N. Y. Edward Weitzen, former president, has resigned to take a post as executive vice-president of Electronic Teaching Laboratories. Ferri, a professor at Brooklyn Poly, was one of the founders of the company.

Vern Hedlund is the new president of the National Association of Relay Manufacturers. He is general manager of the R-B-M Controls Div. of Essex Wire Corp.

C. P. Clare has become chief executive officer of Universal Controls, Inc., New York. Clare is presently executive vice-president and director of Universal and president of C. P. Clare and Co., a subsidiary of the corporation. He has also been active as a director of American Totalizer Co., a division of Universal Controls. Morris Mac Schwabel, who was Universal president, is on a leave of absence pending the outcome of a Federal grand jury indictment on securities fraud charges.

R. S. Bowditch is now chief engineer of the Electronics Div. of Statham Instruments, Inc. in Los Angeles. He comes to Statham from ERA Pacific, where he was general manager and chief engineer.

Samuel L. Sola, who was assistant to the chief of Mechanical Systems Engineering at Nortronics Div. of Northrop Corp., has taken a position with the Aeronutronic Div. of Ford Motor Co. in Newport Beach, Calif. Sola will be manager of automotive design. Among the applications of the division's space age talents being investigated for automobile use are traffic control systems and vehicle instrumentation.

Warren H. Chase, vice-president of the Ohio Bell Telephone Co., has been nominated by the American Institute of Electrical Engineers to be 1961-62 president. Balloting will be by mail among the Institute's 55,000 members. Results will be announced at AIEE's Summer General Meeting in Ithaca, N.Y. in June.

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8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	278	292	306
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476	487	498	509	520	531	542	553	564	575	586	597	608	619	630	641	652	663	674	685	696	707
477	488	499	510	521	532	543	554	565	576	587	598	609	620	631	642	653	664	675	686	697	708
478	489	500	511	522	533	544	555	566	577	588	599	610	621	632	643	654	665	676	687	698	709
479	490	501	512	523	534	545	556	567	578	589	600	611	622	633	644	655	666	677	688	699	710
480	491	502	513	524	535	546	557	568	579	590	601	612	623	634	645	656	667	678	689	700	711
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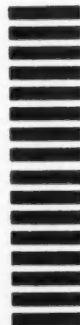
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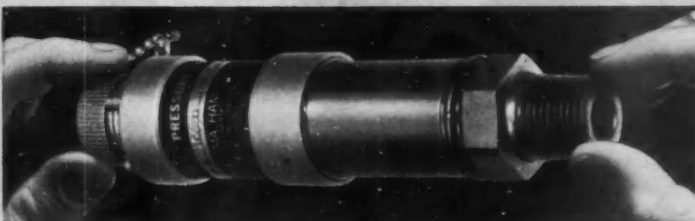
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ABSTRACTS

Two Russian controllers

From "Electronic Extremum Controllers", by R. V. Kornilov. *Instrument Construction*, April 1960, pp. 11-13. Translated from Russian by Taylor & Francis Ltd., London.

It is often necessary in industrial process control to maintain some parameter at an extremum (either maximum or minimum) for greatest efficiency or economy. Preference should always be given to programmed control systems or systems using additional pulses. When such methods will not work (for example, maintaining optimum fuel/oxidizer ratio in a complex heating oven when it is not possible to measure the flow of the oxidizer entering the reaction) then controllers with searching devices should be used.

In the system described, the control signal is formed by the difference, including the sign, between the measured value of the controlled condition y_t and the stored value y_{t-1} , memorized during time interval Δ . When searching for a maximum, with the actuator moving in the right direction, $\Delta > 0$, while with the actuator moving in the wrong direction, $\Delta < 0$.

When the static characteristic of the plant varies with time, a system based on measuring increments is sometimes unable to decide the correct direction to move since displacement in either direction results in a positive increment. A reversing device operating at time intervals t_k can be used to stabilize such a system; the actuator then oscillates with amplitude Δx , and the departure of the system from the extremum is smaller. Since process lags can cause spurious reversing, it is advisable not to reverse every time $\Delta < 0$, but only when the sequence $\Delta > 0, \Delta < 0$ occurs.

The searching device should behave as follows: 1) measure the increment $\Delta = y_t - y_{t-1}$ and determine its sign. 2) Not reverse the actuator when $\Delta > 0$. 3) If Δ remains greater than zero for a time longer than t_k reverse the actuator. 4) Reverse the actuator if $\Delta > 0$ becomes $\Delta < 0$. 5) If there is a series of $\Delta < 0$, then after reversing normally the first time the second reversing should take place with a delay of t_k after Δ changes sign.

An electronic controller with these characteristics consists of a sign relay that detects the sign of the input signal; a gate that selects the appro-

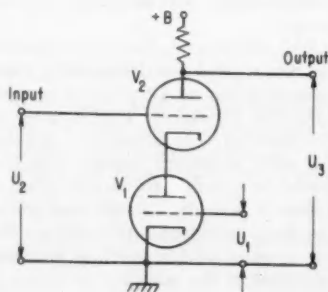
appropriate signal from the series of input signals of the same sign and sends out a signal whenever the increment changes sign; a trigger that provides a compulsory reversal, after a predetermined interval, of a bistable circuit at the output; a differentiating unit that returns the trigger to its original position whenever $\Delta > 0$ changes to $\Delta < 0$; the bistable output circuit that memorizes the direction of movement during the interval between the two consecutive signals received from the trigger; and an output amplifier that provides sufficient power for operating the actuator.

From "A Method of Varying the Gain of Amplifiers in Electronic Controllers", by A. L. Abrukin. *Instrument Construction*, May 1960, pp. 29-31. Translated from Russian by Taylor & Francis Ltd., London.

The methods presently used to change the gain of an amplifying stage are not very effective (small degree of variation of gain). Also, the signal causing the gain variation has to have a magnitude on the order of tens of volts. The basic circuit of a variable gain amplifying stage which operates from a controlling signal on the order of $\frac{1}{10}$ volt is shown in the Figure.

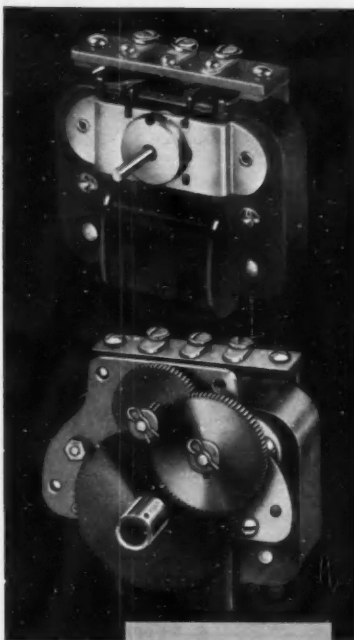
The input voltage U_1 is applied to the grid of V_2 . Variations in the dc biasing voltage U_1 applied to the grid of V_1 change the equivalent resistance in the cathode circuit of V_2 . It is this variation in the negative feedback which varies the gain and the output voltage U_2 . Best results are obtained with a high- μ triode section for V_2 and a high g_m section for V_1 . With some tubes it may be necessary to put positive bias on the grid of V_2 for good linearity.

Two of these circuits are used in a self-adjusting controller intended to stabilize the homing signal in remote control equipment. A variation in output power from 0 to 20 watts causes a variation of 0.3 to 0.4 volts at a 25-volt level.



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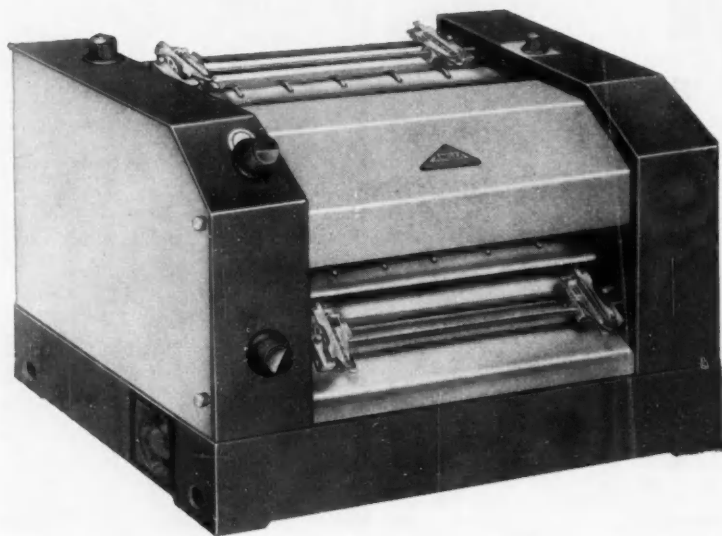
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ABSTRACTS

CO₂ measures pulsating flow

From "Gas-Tracer Method of Steady and Pulsating-Flow Measurement", by J. F. Kemp, National Mechanical Engineering Institute, Pretoria, South Africa. Paper No. 60-WA-142 presented at the Winter Annual Meeting of the American Society of Mechanical Engineers, New York, Nov. 27-Dec. 2, 1960.

Common methods of measuring mass flow rate in air streams are inadequate when the stream pulsates severely. One way of getting around this problem is to put a tracer gas into the main flow, allow the two media to mix, and then sample and analyze the mixture to determine the mass concentration of the tracer. Applying the law of mass conservation, the mean gas flow rate G of the main gas stream is given by

$$G = \frac{g(1 - c_1)}{(c_1 - c_0)}$$

where g = injection mass-flow rate of tracer, c_0 = mass concentration of tracer in main stream before injection, c_1 = mass concentration of tracer in a representative sample.

A convergent nozzle, operated at a constant injection pressure well above the value that yields sonic speed in the throat, can be used to inject the tracer. Such a nozzle is easy to calibrate in injection flow rate, and the rate is not affected by pressure variations in the main flow.

A sufficiently long duct will insure complete mixing, in which case the sample can be drawn off through a single probe or a hole in the side of the duct. Or a multiple probe pulling samples from several areas of the duct into a common manifold can be used to secure a representative sample.

The tracer gas itself should be harmless to the materials in the system, cheap, and nontoxic. It should also lend itself to accurate analysis when present in low concentrations. Carbon dioxide meets all of these requirements.

An inexpensive infrared analyzer was constructed for determining mass concentrations of CO₂ in air ranging from 1/2 to 3 percent. The accuracy of this analyzer was about 2 1/2 percent, and with suggested improvements it should be possible to increase this to around 1 percent. Steady and pulsating flow measurements indicate that the accuracy of the method is essentially that of the analyzer.

NEW BOOKS

Control Theory Text

ADAPTIVE CONTROL SYSTEMS.
Edited by Eli Mishkin and Ludwig Braun, Jr., 533 pp., published by the McGraw-Hill Book Company, Inc., New York. \$16.50.

The broad area in control theory called adaptive control is covered in this collection of discrete topics contributed by a number of authors. Most books put together this way have been unsatisfactory, in this reviewer's experience, but this is an exception.

About half the book provides background. The first chapter explains the basic concept of adaptive control and points out the nature of the adaptive problem and its growing importance. Highlights of linear theory are presented in Chapters 2-5. Signal flow graphs, the identification process, and sampled-data theory are treated, not exhaustively, but with emphasis on what will be useful in studying the adaptive problem. It is assumed that the reader has a reasonable background in control theory, but these chapters are so well written that they should prove interesting and informative to readers whose background is relatively meager.

Chapters 6-8 summarize nonlinear theory in a similar fashion. Topics include describing functions, models, intentional nonlinearities, and phase plane techniques. Chapters 9-12 treat adaptive control systems themselves. In each chapter specific methods or systems are considered and analyzed and illustrative results given. A great variety of methods and systems are covered, but more discussion in detail would have been an improvement; only 104 pages are used to present the nominal subject of the book. Chapters 13-17 introduce various mathematical techniques of value in adaptive control theory.

This is one of the best of the recent advanced texts in control theory and is well worth reading carefully.

George J. Thaler
U. S. Naval Postgraduate School

Why Failure?

ELECTRONIC EQUIPMENT RELIABILITY. G. W. A. Dummer and N. Griffin, 269 pp., published by John Wiley & Sons, Inc., New York. \$7.50.

This is a painstaking investigation of electronic equipment failure and methods to reduce it. The book's

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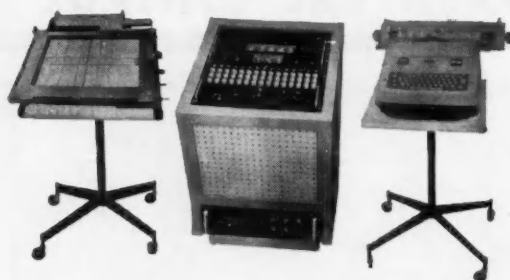
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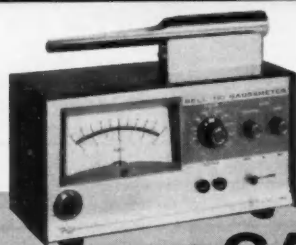


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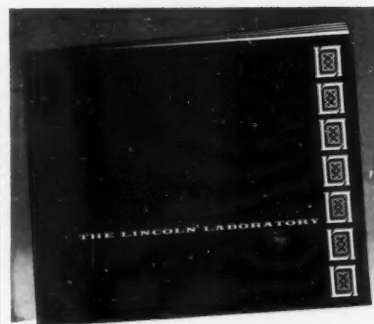
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CONTROL ENGINEERING

NEW BOOKS

greatest shortcoming is a nearly complete lack of information on semiconductors. The authors hope to provide more in a second edition, but this does not help the first edition.

Statistical occurrence and prediction of equipment and component failures and the effects of environmental conditions and design details on reliability are discussed, and there is a chapter on human engineering. Many preferred circuits published in 1954 by the National Bureau of Standards are listed. Testing and inspection are covered in a separate chapter. The bibliography at the end of the book is most complete for the years 1952 to 1956, but no publications after 1958 are listed.

Some of the interesting conclusions reached after examining a large amount of data confirm facts that are commonly accepted but often ignored. For example, the failure rate increases exponentially with equipment complexity as measured by the number of tubes or transistors. Also, few military components fail from wearout; they fail statistically with the chance law.

Discussion of vacuum tubes occupies considerable space in this book. For example, about half the chapter on Faults in Equipment, Valves and Components is about tubes; the remainder is on resistors, capacitors, cables, wires, sleeves, plugs, sockets, relays, switches, transformers, and indicators, but not transistors.

Werner G. Holzbock
Birmingham, Michigan

Terminology Explained

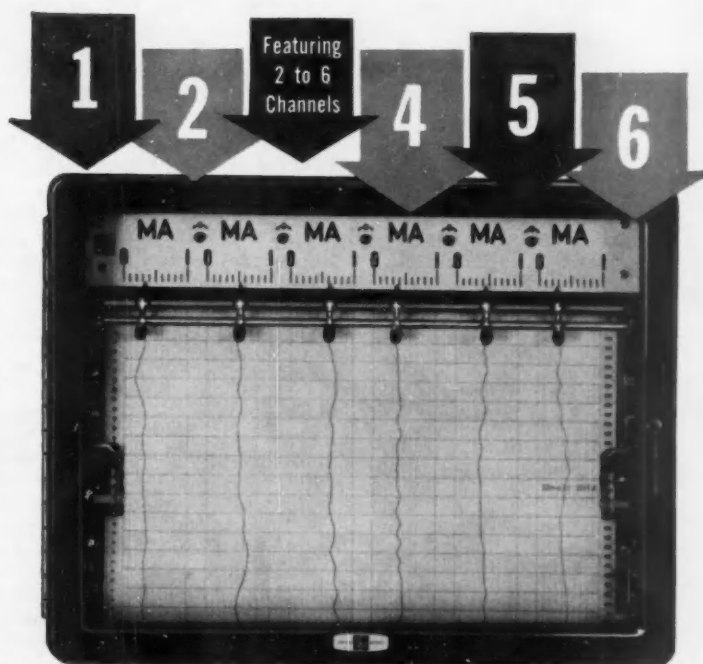
DIGEST OF MILITARY ELECTRONICS.
205 pp. Published by the RCA Service Company, Camden, N. J. \$3.95.

This handy reference lists and defines some 560 names given to military electronic equipment and systems. Arranged alphabetically from "absolute altimeter" to "zone position indicator" with plenty of cross references, the list includes nicknames, acronyms, and contractions (Hermit, COZI, RACON, and the like). Navigation and tracking equipment, missiles, countermeasures, and communications systems are all covered. Of necessity the definitions emphasize what a device does rather than how it works, but performance specifications are often included and there are several system block diagrams.

APRIL 1961

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MEETINGS

APRIL

Instrument Society of America, 13th Annual Symposium-Electronic Process Instrumentation, sponsored by N.J. Section, Hotel Essex House, Newark, N.J. April 4

Third Symposium on Information and Decision Processing, sponsored by IRE and Purdue University, Purdue University, Lafayette, Ind. April 12-13

Instrument Society of America, Seventh National Symposium on Instrumental Methods of Analysis, Shamrock-Hilton Hotel, Houston, Tex. April 17-19

Institute of Radio Engineers, 13th Annual Southwest IRE Conference and Electronic Show (SWIRECO), Dallas Memorial Coliseum, Dallas, Tex. April 19-21

Institute of Radio Engineers, Seventh Region Technical Conference and Trade Show, Westward Ho Hotel, Phoenix, Ariz. April 26-28

Instrument Society of America-Seventh National Aero-Space Instrumentation Symposium, Adolphus Hotel, Dallas, Tex. April 30-May 4

MAY

Electronic Components Conference, Sponsored by IRE, AIEE, EIA, Jack Tar Hotel, San Francisco, Calif. May 2-4

Institute of Radio Engineers, Second National Symposium on Human Factors in Electronics, Marriott-Twin Bridges Motor Hotel, Arlington, Va. May 4-5

Institute of Radio Engineers, 13th Annual National Aerospace Electronics Conference (NAECON), Miami and Biltmore Hotels, Dayton, Ohio May 8-10

Instrument Society of America, Fourth National Power Instrumentation Symposium, LaSalle Hotel, Chicago, Ill. May 8-10

Western Joint Computer Conference, sponsored by IRE, ACM, AIEE, Ambassador Hotel, Los Angeles, Calif. May 9-11

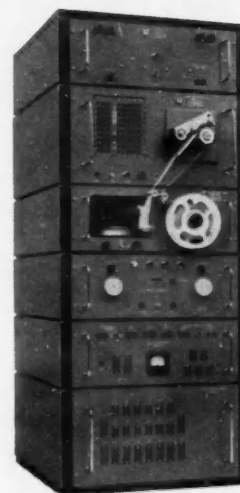
International Exhibition of Measurement, Control Regulation and Automation (MESUCORA), Exhibition Hall, Centre National des Industries et des Techniques, Paris, France May 9-17

Instrument Society of America, Pulp and Paper Instrumentation Sym-

(Continued on page 217)

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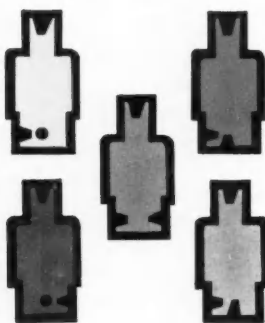
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MEETINGS

MAY (Continued)

posium, Northland Hotel, Green Bay, Wis. May 10-12
American Institute of Industrial Engineers, 12th Annual National Conference and Convention, Sheraton Cadillac Hotel, Detroit, Mich. May 11-13
Fifth National Symposium of Global Communications (Globecom V), sponsored by AIEE, IRE, Hotel Sherman, Chicago, Ill. May 22-24
Tenth National Telemetry Conference, sponsored by IRE, AIEE, IAS, ARS, ISA, Sheraton-Towers Hotel, Chicago, Ill. May 22-24
Symposium on Large Capacity Memory Techniques for Computing Systems, sponsored by Information Systems Branch of Office of Naval Research Dept. of Interior Auditorium, Washington, D.C. May 23-25

JUNE

Instrument Society of America, Summer Instrument-Automation Conference and Exhibit, Royal York Hotel, and Queen Elizabeth Hall, Toronto, Canada June 6-8
Instrument Society of America, Third Biennial International Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich. June 13-16
Institute of Radio Engineers, Fifth National Conference on Product Engineering and Production, Sheraton Hotel, Philadelphia, Pa. June 14-15
Association for Computing Machinery, Computer Conference on Business Languages, Western Reserve University, Cleveland, Ohio. June 15
American Institute of Electrical Engineers, Summer General Meeting, Willard Straight Hall, Cornell University, Ithaca, N.Y. June 19-23
Denver Research Institute of University of Denver, Eighth Annual Symposium on Computers and Data Processing, Elkhorn Lodge, Estes Park, Colo. June 22-23
Institute of Radio Engineers, Fifth National Convention on Military Electronics (MILE-CON 1960), Shoreham Hotel, Washington, D.C. June 26-28
Second Joint Automatic Control Conference, sponsored by IRE, ISA, AIEE, AICHE, ASME, University of Colorado, Boulder, Colo. June 28-30



THE SPARE PARTS PROBLEM

The Electronics Business may not be the most tranquil enterprise for anyone to get into—either as a buyer or seller—as evidenced by one of the problems currently plaguing both component makers and their customers. In a nutshell, the trouble is "equivalent" parts, made by a low bidder, failing to behave as the originals did. The explanation, while not as simple as this, seems to boil down to the fact that specs and descriptive data alone aren't enough for anyone to duplicate the performance of somebody else's original part. It could be a matter of the inability of the blueprint and the mimeograph machine to be a satisfactory substitute for the original manufacturer's experience, engineering skill, assembly methods and quality control.

No one can argue the merits of saving money, and a good part at the lowest possible cost is a commendable achievement. But when "low quote" means failure of critical equipment and personal hazard,

there's not much to be said for economy. On the other hand, if the low man *does* get all the information he needs to build an exact replacement of the original part (assuming he can build it), he is automatically getting the benefit of a great deal of work done and paid for by the original manufacturer. The polite term is usually "proprietary data." Understandably, this arouses the "unfair competition" ogre.

We don't like to give away proprietary information any more than the next person. Neither do we like to see unreliable components endangering life and limb. We think part of the answer may be to give the second man the same *problem* you gave the original supplier—not the blueprinted solution to imitate. Then test his result as carefully as you did the original successful one. This way, the odds are strongly in favor of your getting something that *will* work—and perhaps work even better.

What do you think the answer is?

* E. W. Schrader, Western Editor of DESIGN NEWS, made some good observations on this whole subject; see pp. 6-7, Jan. 16 issue.

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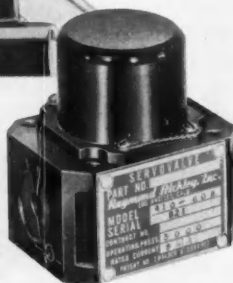
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WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient fileable form. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 203. Don't send money with card, we will bill you later. For multiple copies write Reprint Dept. Quantity rates will be quoted on request.

508—Transistor Switches for Industrial Service, March 1961, 24 pp. Industry requires reliable, inexpensive, and fast switching devices. This special report thoroughly covers one possible solution to this requirement—transistor logic modules packaged for industrial use. Topics include: how transistors perform logic functions, available systems and components, tips on selection and use, and case studies of industrial applications. 65 cents.

507—Tips on the Use of Electromechanical Relays, 24 p. Compilation of five articles presents practical information on the design, test, and use of relay control systems. Topics covered include: testing relay electrical reliability, improving system reliability, narrowing relay differential, logical synthesis of systems, and verifying relay control circuits. 65 cents.

506—What You Should Know About Adaptive Systems, 17 pp. Is there such a thing as an adaptive control system? What approaches have been taken? What does the future hold? These are the questions the author answers in this three-article reprint, in sufficient detail and with sufficient references to provide a basic grounding in this latest area of control engineer interest. 50 cents.

505—The Basics of Optimum Response Relay Servos, 17 pp. Three part series summarizes all of the important design techniques that have been used to optimize the response of relay servos. The reprint describes the development of the optimum switching criteria, and outlines the progress that has been made in implementing this theory with hardware for second-order and higher-order systems. Extensive references provide a guide for further study. 50 cents.

504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern

(Continued on page 220)



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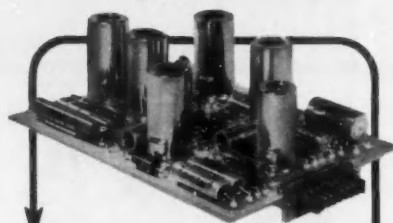


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techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—How to Determine Stream Analyzer Dynamics, 8 pp. This package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

502—Survey of Dynamic Display Techniques, 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical systems, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—Six Transducers for Precision Position Measurement, May 1960, 6 pp. Explains operation and gives practical application hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

500—Ready Reference Data Files—I, II, III, 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in *CONTROL ENGINEERING* through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. \$1.35.

499—Ready Reference Data Files—III, 28 pp. Includes the third dozen Data Files published in *CONTROL ENGINEERING*. Topics range from control of metal properties with eddy currents to electrically signaled valve actuators to stabilization of sampled data systems. 60 cents.

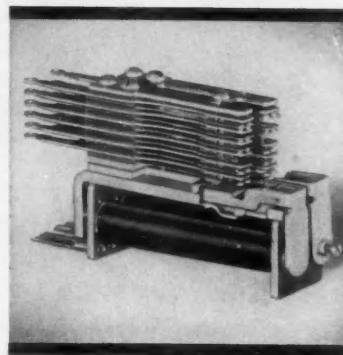
498—Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in *CONTROL ENGINEERING*. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

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496—How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

495—Transparent Template for Designing Servo Compensators, November 1959, (Continued on page 223)

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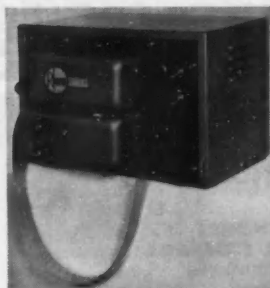
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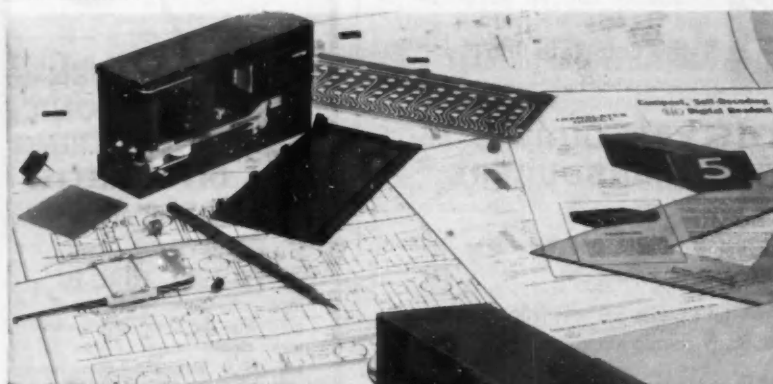
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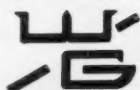
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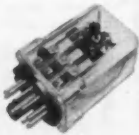
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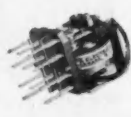
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487—Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Regarded as constant speed devices, multi-speed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

486—A New Way to Select the Best Control Valve, 16 pp. This three-article reprint takes a fresh look at the problem of specifying process flow control valves. The author gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

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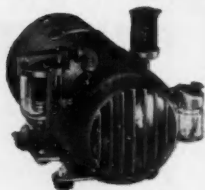
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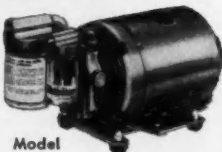
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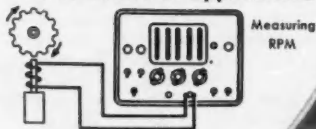
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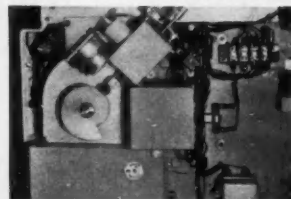
483—**Economics in Control**, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

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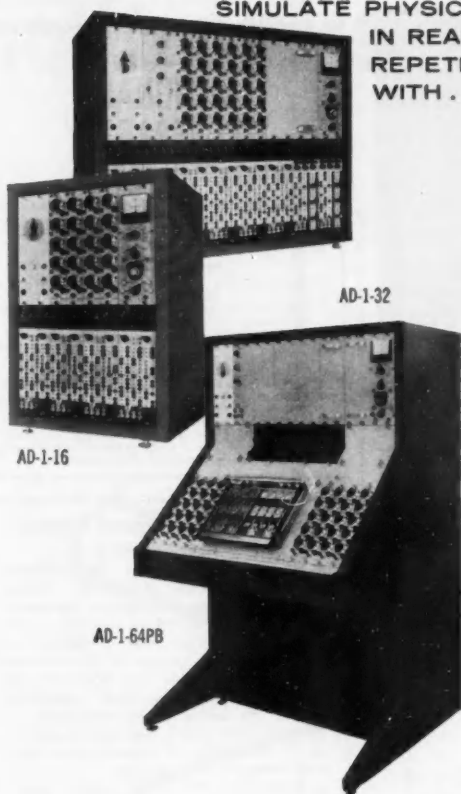
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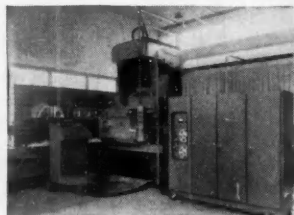
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Employment Opportunities



The advertisements in this section include all employment opportunities—executive, management, technical, selling, office, skilled, manual, etc.

— RATES —

DISPLAYED: The advertising rate is \$42.50 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request. An advertising inch is measured $\frac{1}{8}$ " vertically on a column—3 columns—30 inches to a page. Subject to Agency Commission.
UNDISPLAYED: \$2.10 per line, minimum 3 lines. To figure advance payment count 5 average words as a line. Box numbers—count as 1 line. Discount of 10% if full payment is made in advance for 4 consecutive insertions. Not subject to Agency Commission.

Design and Development Engineer

Intermediate Grade

A leading manufacturer of automatic temperature controls in northern Chicago suburb is seeking a graduate mechanical engineer from accredited university with 2 to 3 years experience in design and development of pneumatic or hydraulic flow controls, valves, recording and controlling instruments or small mechanical devices. He should be an imaginative, individual with sound mechanical aptitude and a knowledge of manufacturing problems, methods and processes.

In return we offer good salary, opportunity for advancement, generous fringe benefits, profit sharing retirement plan, attractive working conditions and professional prestige.

Please send a resume describing your education, experience, accomplishments, personal information and salary.

Write R. G. Steckel

The Powers Regulator Co.
 3400 Oakton St., Skokie, Ill.

SENIOR DIGITAL DATA SYSTEMS ENGINEER

Capable of overall data acquisition and processing systems conception and project management. Career opportunity with growing small company in Connecticut. Salary open.

P-0278, Control Engineering
 Class. Adv. Div., P.O. Box 12, N.Y. 36, N.Y.

SENIOR ELECTRICAL ENGINEERS

Sun Electric Corporation needs senior electrical engineers with instrument experience in specifications, application engineering design and development of permanent magnet moving coil instruments and associated components.

This is an opportunity for increased professional status and growth potential to work in a progressive firm having a reputation for the finest quality products in the industry.

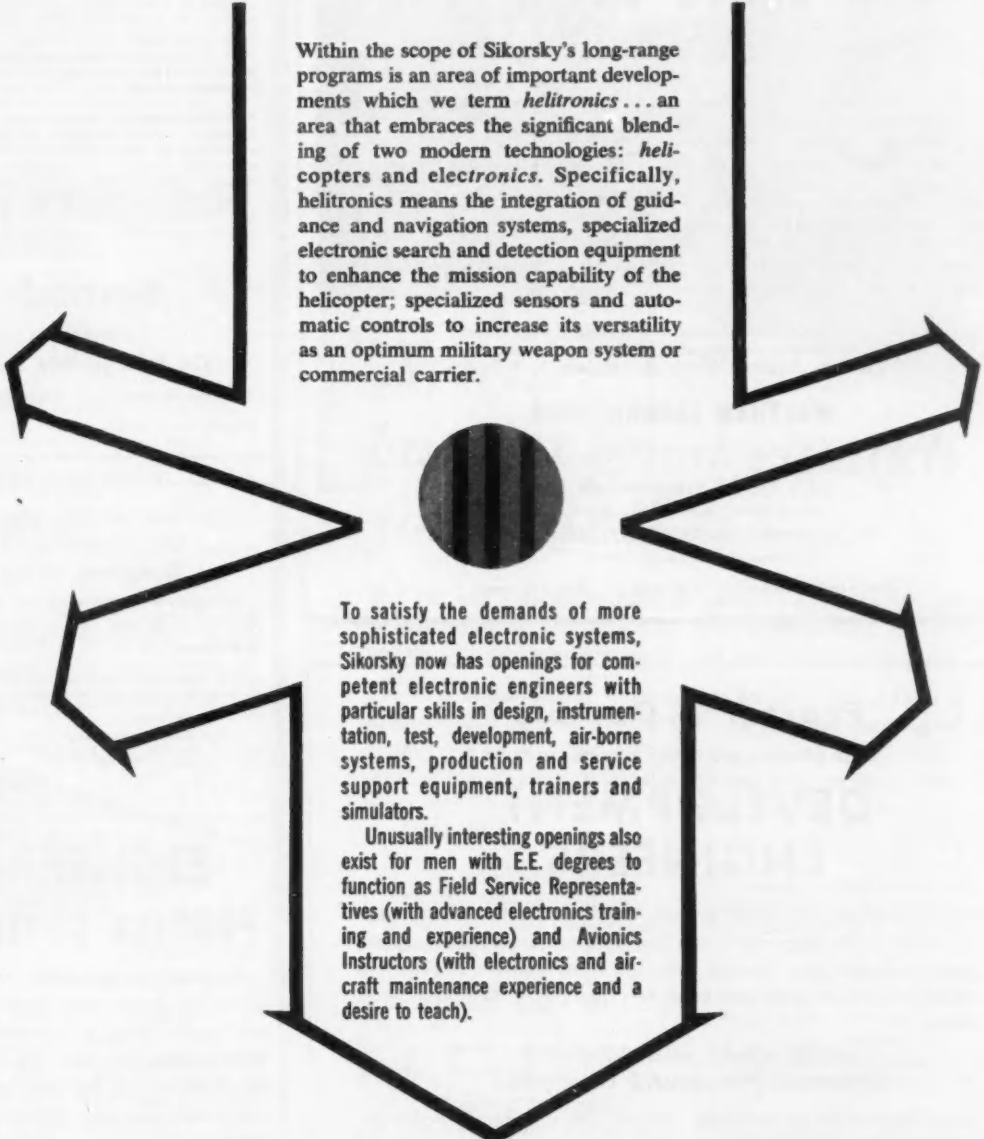
We offer excellent salary, liberal benefits, progressive management policy and professional opportunities in a modern suburban location.

Submit detailed resume stating education, experience and salary requirements to the Director of Personnel.

SUN ELECTRIC CORPORATION
 Avondale and Harlem Avenues
 Chicago 31, Illinois

CONTROL ENGINEERING

helitronics... new avenues of creative engineering at Sikorsky Aircraft



Within the scope of Sikorsky's long-range programs is an area of important developments which we term *helitronics*... an area that embraces the significant blending of two modern technologies: *helicopters* and *electronics*. Specifically, *helitronics* means the integration of guidance and navigation systems, specialized electronic search and detection equipment to enhance the mission capability of the helicopter; specialized sensors and automatic controls to increase its versatility as an optimum military weapon system or commercial carrier.

To satisfy the demands of more sophisticated electronic systems, Sikorsky now has openings for competent electronic engineers with particular skills in design, instrumentation, test, development, air-borne systems, production and service support equipment, trainers and simulators.

Unusually interesting openings also exist for men with E.E. degrees to function as Field Service Representatives (with advanced electronics training and experience) and Avionics Instructors (with electronics and aircraft maintenance experience and a desire to teach).

For further information, submit your resume or make inquiry to J. L. Purfield, Personnel Department.



pioneer and leading manufacturer of rotary wing aircraft

SIKORSKY AIRCRAFT

Division of United Aircraft Corporation

STRATFORD • CONNECTICUT

SERVO ENGINEERS

Staff Assignments at all Levels IN NEW SERVO DEPARTMENT

of Sylvania Waltham Laboratories

The mission of this new department is to intensify and extend the company's already vigorous efforts to apply sophisticated concepts of servo technology to increasingly complex, large-scale electronic systems. Typical problems are concerned with creating a new and unprecedented degree of precision for artillery tracking radars and satellite tracking antennas.

Positions are currently open at all levels of experience to men with BS, MS or PhD:

SERVO SYSTEMS ENGINEERS**SERVO CIRCUIT SPECIALISTS**

Transistor and vacuum tube

SERVO ENGINEERS

Instrument and servo transducers

Servo engineers interested in associating themselves with a dynamic and growing professional group are invited to inquire. Write Mr. Robert T. Morton

WALTHAM LABORATORIES

100 First Avenue — Waltham 54, Massachusetts

Procter & Gamble

Has permanent staff openings for

DEVELOPMENT ENGINEERS

A planned program for steady growth, the diversification of the company's business into paper products and cellulose, new food products and new detergents has created openings in our modern Engineering Development Labs for graduate engineers qualified to handle projects involving:

INSTRUMENTS AND CONTROLS CHEMICAL PROCESSING EQUIPMENT

This is an opportunity to associate yourself with a company noted for its stability and consistent growth—one nationally recognized for its personnel policies, unexcelled working environment, opportunities for technical advancement and long range careers.

Experience desirable but not essential. Salaries commensurate with experience. Send letter in confidence outlining education, experience and salary desired to:

Mr. L. E. Hart, Dept. EDD-2
Procter & Gamble Company
Engineering Division, I. T. C.
Cincinnati 17, Ohio

INSTRUMENT ENGINEERS

Major west coast engineering and construction firm has openings for senior engineers experienced and qualified in instrumentation and/or systems engineering. To assume full job responsibility on a project level for the instrumentation and control of processing, industrial and power plants. Would prefer experience in electronic control and digital information systems.

Relocation allowances cover moving costs plus transportation reimbursement for you and members of your family. If you have an interest in a San Francisco assignment, please send a resume of experience, including your present and required salary, to George I. Copeland, Manager of Personnel. A personal interview will be arranged for qualified applicants.

Bechtel

Corporation

220 Montgomery Street
San Francisco, California

LOUGHBOROUGH COLLEGE OF TECHNOLOGY

Leicestershire, England

Applications are invited for the post of Assistant to the Director of Digital Computer Operation. Applicants should have some experience of digital computer work and preferably should hold graduate qualifications.

Salary on a basic scale of £700—£1,150 per annum, with additional allowances for graduates and training. The starting point on this salary scale will be fixed according to qualifications and previous experience.

Forms of application and further particulars may be obtained from the Academic Registrar. (In reply please quote ref. 2/ BE.)

ENGINEER - PROCESS CONTROL

Excellent opportunity for experienced engineer in development and application of automatic controls to petroleum refining processes. Applicant should be chemical engineer with electronic experience or electronics engineer with process experience.

Excellent fringe benefits including profit sharing. Please submit resume, giving education and professional experience. Write to:

D. E. LEWAN
Universal Oil Products Company
30 Algonquin Road
Des Plaines, Illinois

Expanding Opportunities in

Industrial Instrumentation with R. I. G.

The Ridgefield Instrument Group, a division of the Schlumberger Corporation, is rapidly widening its research and production activities to include the abilities of more creative engineers and scientists.

Challenging openings now exist for:

ELECTRONIC DESIGN ENGINEER

BS or MS/EE with a minimum of 5 years experience in tube and transistor circuit design. You must have the ability to analyze continuous and pulsed circuits and be able to develop original designs.

At RIG you will design advanced circuitry and control instruments and establish sub-system specifications. You must assume project responsibility through prototype stage.

INSTRUMENT ENGINEER

BS in either Mechanical or Chemical Engineering, Engineering Physics or Physical Chemistry with 3-5 years experience in instrument design and application for the process industries. You must have creative ability in reducing ideas, theory and inventions to practicality. You should have knowledge of selection, application and maintenance of process control instrumentation.

send resume to
Director of Engineering
P.O. Box 337

**RIDGEFIELD
INSTRUMENT
GROUP**

Ridgefield
Connecticut

Division of Schlumberger

RADAR SYSTEMS

\$18,000

High performance search radar, missile tracking and guidance radar and counter measure systems. High level position in new R & D laboratory. E. E. degree plus 5 or more years experience. Company client will assume all employment expenses. Contact in confidence.

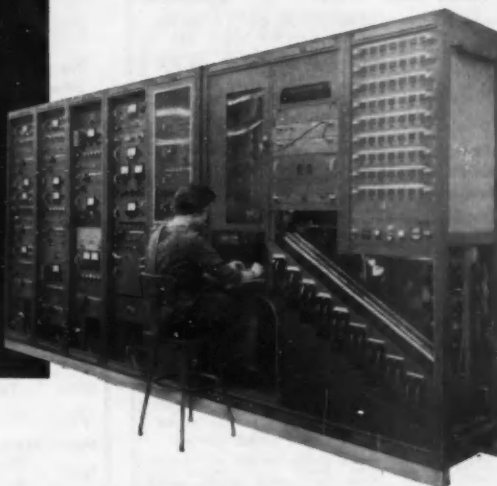
ESQUIRE PERSONNEL
202 S. State Street Chicago 4, Illinois

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Engineering • Consulting • Proposal Assistance
Magnetic Recording Systems
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Drums, Discs, Photoreaders, Circuitry
3300 West Peterson, Chicago 45
IRving 8-9850

Engineers

Automatic semiconductor test system developed and constructed in the laboratories of General Electric's Semiconductor Products Department in 1960



*"New...
but not good enough
for 1962!"*

The test and classifying machine pictured performs 10 parameter measurements on each transistor faster than the best rate of 5 technicians with previous equipment, and with complete accuracy.

The SPD engineers who developed it can be proud of their achievement... but they also realize that the next generations of semiconductors (now in basic or applied research here) will call for still further advanced manufacturing and test equipment. This is one more step toward G.E.'s goal of Quality Volume Leader in the semiconductor field.

A HIGH ORDER OF ENGINEERING INNOVATION

is required to develop these manufacturing and test systems. Largely responsible are the unusual characteristics of the semiconductors themselves—their small overall size, internal components "measured - to - millionths," contamination safeguards, precise positioning, joining and sealing.

IMMEDIATE OPENINGS

are offered to engineers who can meet the challenge of developing manufacturing or test equipment which success-

fully integrates high speed automatic operation with the startlingly high precision requirements of semiconductors.

Your experience as an equipment or systems design engineer on many types of military or industrial automation and process control equipment can qualify you immediately. Minimum degree requirements are BS in Physics, EE, ME or ChE.

To apply, or get further information, write in confidence to Mr. J. H. McKeehan, Dept. 22-MD.

SEMICONDUCTOR PRODUCTS DEPARTMENT

GENERAL  ELECTRIC

Electronics Park • Syracuse, New York

Other openings
at three
General Electric
facilities...

Syracuse: Advanced Semiconductor Laboratory, Advanced Transistor Engineering, Process Development, Manufacturing Equipment Development. Buffalo: Manufacturing Process Engineering, Quality Assurance Engineering. Auburn: Rectifier and Diode Development and Process Engineering.

"TAB" SILICON 750MA* DIODES TOP HATS

rms/piv 17/25 14c	rms/piv 35/50 29c	rms/piv 70/100 29c	rms/piv 140/200 34c
rms/piv 210/300 43c	rms/piv 280/400 55c	rms/piv 350/500 70c	rms/piv 420/600 \$1.00
rms/piv 480/700 \$1.25	rms/piv 580/800 \$1.80	rms/piv 680/1000 \$1.70	rms/piv 700/1000 \$2.00

Low Priced *7200 Silicon Diodes rated 380 piv/266rms @ 200 MA. @ 100°C 36c each; 10 for \$3.25; 100 for \$27; 1000 for \$230.
* CAPACITOR INPUT DERATE 20% (85 or more this item we pay P.P./U.S.A.)

SPECIAL TRANSISTORS & DIODES! FULL LENGTH LEADS

Factory Tested & Guaranteed! U.S.A. Mfg!
2N441 PNP-PWR-\$2 @ 6 for \$11, 100/\$140
2N442 2N277 \$2.95, 6for\$17, 100/\$250
Write for QTY Prices! Export & O.E.M.

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2N292 NPN 45c ea., 12 for \$5, 100 for \$37
2N293 NPN 45c ea., 12 for \$5, 100 for \$37
2N223 PNP 80c ea., 12 for \$9, 100 for \$65
2N597 PNP \$1.90 ea., 6 for \$10
2N598 PNP \$1.90 ea., 6 for \$10
2N599 PNP \$3.80 ea., 3 for \$10
2N670 PNP/300 MW 95c ea., 8 for \$5, 100 for \$48
2N671 PNP/1W \$1.15 ea., 5 for \$4, 100 for \$59

GENERAL PURPOSE-PNP-COMPUTER GRADE!
Use as Amplifier-Oscillator-Hi-Fi-Logic-Servo-
Switch-Power Supply Pulse Amplifier or High Current
Switch. Vch. Vce. Veb Approx. 40V
GP 3C rated 300 Milliwatts 65c ea., 10 for \$5,
100 for \$39.
GPLOC rated one watt c90ea., 6for\$5, 100/\$63

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\$1.75, 2N247 \$1.50, 2N255 \$1.20, 2N270 \$95
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\$1.00, 2N579 \$1.00, 2N581 \$1, 2N582 \$2.10,
2N174 \$8.50, 2N443 \$6.50, 2N670 \$1.80, 2N671 \$2
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KIT TRANSISTORS NPN 35c ea., 3 for \$1.
KIT TRANSISTOR PNP 35c ea., 3 for \$1.

TOP HAT SILICON DIODE EXPERIMENTERS KIT
USE AS STUDY, ZENER DIODES & WETTER
PROTECTION DIODES, CLIPPER & RECTIFIER
DIODES! A \$10 VALUE, 8 for \$1, 100 for \$10

QTY Discounts to Volume Buyers
(\$10 or more this item we pay P.P./U.S.A.)
"SUNTAR" * SELENIUM PHOTOCOLL
2BP 75uA 3x4 1/2" c40 @
11 for \$4
5AP 1" Dia. SPS/SocRect
220Vua. c58 @ 12for\$6
15AP 750ua. 1 1/2" Dia.
c11.25 @ 4 for \$5
10BP 350ua., 1-1 1/2" Rect.
c11.25 @ 4 for \$5
10CP 750ua. 1-7/8x1 3/8"
c14.25 @ 4 for \$5

This Item Shipped Postpaid Orders \$10 Up
NEW Selenium Radio & TV Rectifiers! GTD
100MA c45 @ 12for\$5, 100/\$39, 150MAc\$5 @
12for\$6, 100 \$49, 250MA c65 @ 11for\$7, 100/\$37,
300MA c72 @ 12for\$8, 100/\$69, 50MA c89 @
12for\$10, 100for\$55.

★ NEW "TERSEL" SELENIUM RECTIFIERS
FULL WAVE BRIDGE RECTIFIERS. ONE YEAR GTD!
AMP. 18VAC 36VAC 72VAC 144VAC
CONT. 14VDC 28VDC 56VDC 112VDC
1AMP \$ 1.30 \$ 2.00 \$ 4.90 \$ 6.50
2AMP 2.15 3.00 6.25 12.30
3AMP 2.90 4.00 8.60 16.75
6AMP 4.15 8.00 18.75 36.15
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Write for Complete Rectifier Catalog

New 24-28VDC Relay Supplies Cased Filtered
Ready to Work-115VAC-50 to 800 cys. Input
B12VGR 12-16VDC @ 2Amps Filtered & CSD \$9.90
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"TAB" SILICON POWER DIODE STUDS* OPERATION UP TO 125° C CASE TEMP.

DC AMP	17 SRms 25Piv	35 SRms 50Piv	70 SRms 100Piv	140 SRms 200Piv
1.5	.45	.45	.60	.80
2	.45	.45	.60	.80
6	.95	1.30	1.90	2.40
12	1.30	2.00	2.60	3.18
18	1.75	2.45	3.10	3.70
35	3.95	5.75	7.90	9.90
70	4.45	6.00	8.45	10.75
240	5.90	8.45	12.60	15.75
DC AMP	140 SRms 200Piv	210 SRms 300Piv	280 SRms 400Piv	350 SRms 500Piv
1.5	.70	.85	1.00	1.35
2	1.00	1.35	1.60	1.95
6	3.00	4.00	6.90	9.00
12	4.90	6.90	11.00	14.75
18	5.60	7.90	11.00	14.75
35	8.60	11.45	16.75	21.00
70	11.45	16.75	21.00	26.30
240	20.00	33.45		

LOW PRICES TO VOLUME BUYERS!
* Derate 20% for battery or capacitive load or D.C.

"VACDAC"® SILICON TUBE REPLACEMENTS
WITH BUILT IN RF SURGE &
SERIES BALANCING
PROTECTION
TYPE VRMS/PIV AMPS PRICE
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"TAB" TERMS: Money Back Guarantee! Our 17th year. \$2 min. order
F.O.B. N.Y.C. Add ship. charge.
or for C.O.D. 25% Dep. Prices
shown subject to change.
111-CE LIBERTY ST., N.Y. 6, N.Y.
Send 25¢ for Catalog
PHONE: RECTOR 2-6245
Circle 251 on Reader Service Card

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BUSINESS OPPORTUNITIES - EQUIPMENT - USED or RESALE

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The advertising rate is \$20.80 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request.

AN ADVERTISING INCH is measured 7/8 inch vert. on one col., 3 columns-30 in. to a page.

EQUIPMENT WAITED or FOR SALE ADVERTISEMENTS acceptable only in Displayed Style.

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\$2.10 a line, min. 3 lines. To figure advance payment count 5 average words as a line.

BOX NUMBERS count as one additional line in undisplayed ads.

DISCOUNT OF 10% if full payment is made in advance for four consecutive insertions of undisplayed ads.

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In Large Quantities
At Fraction of Original Cost

Maker	Type	Contact Arrangement	Resistance	Voltage	Price
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		2A2C	39 Ohm	6VDC	1.50
Sigma	82JOCA-8010	1A1C	16,000 Ohm	28VDC	3.00
Sigma	7-JOZ-90030	SPDT	5000 Ohm	28VDC	2.50
		None Pile Up Cont.			
		3A3B	144 Ohm	12VDC	1.00
		3B	144 Ohm	12VDC	1.00
		1A1B2C	39 Ohm	6VDC	1.00
		1C1A	200 Ohm	12VDC	1.50
Phillips	2QA316A Control	SPST	300 Ohm	24VDC	1.50
Clare	B65369	1A1B	125 Ohm	12VDC	1.50
RBM	RB22300-14	1A1B	200 Ohm	28VDC	1.50
Potter- <td>KF-1012-4</td> <td>SPST</td> <td>200 Ohm</td> <td>12VDC</td> <td>1.50</td>	KF-1012-4	SPST	200 Ohm	12VDC	1.50

Minimum Order \$25.00
LIBERTY ELECTRONICS, INC.
582 Broadway New York 12, N. Y.
Phone: WA 5-6000 Cables: Telsersup
Circle 252 on Reader Service Card

if you purchase TUBES & SPECIALIZED ELECTRONIC COMPONENTS...

THE NEW 1961 BARRY GREENSHEET IS A MUST!
Circle Reader Service Card No. 254 for your copy.
A Complete 48 Page Electronics Buyers' Guide
BARRY ELECTRONICS CORP.
512 Broadway • New York 12, N. Y. • Walker 5-7000
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FROM 250 MA TO 6-12-18 & 35 AMP
FACTORY DIRECT. Exclusive Distributors for Name Brands. Immediate Delivery. All Types
750 MA. RECTIFIERS GUAR.
Input Working Range RMS/ACV Res. or Cap.
PIV/RMS PIV/RMS PIV/RMS PIV/RMS
50/35 100/70 200/140 300/210
.15 ea. .25 ea. .30 ea. .40 ea.
PIV/RMS PIV/RMS PIV/RMS PIV/RMS
400/28J 500/350 600/420 700/480
.65 ea. .75 ea. .90 ea. .90 ea.
PIV/RMS PIV/RMS PIV/RMS PIV/RMS
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SPECIAL! All Purpose Rectifier 400 piv @ 250ma
\$3.25 ea. 25 for \$7.50
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WRITE QTY PRICES
All Material Guaranteed. \$2.00 min. order. Orders
F.O.B. NYC. Include check or money order. Ship
charges plus. C.O.D. orders 25% down.
WARREN DIST. CO.
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Circle 253 on Reader Service Card

DID YOU KNOW . . . ?

That when buyers are in the market for a specific piece of used or rebuilt equipment . . . they turn to the

SEARCHLIGHT SECTION

SEARCHLIGHT Equipment Locating Service

NO CHARGE OR OBLIGATION

This service is designed to help you, the potential buyer of used, rebuilt or surplus equipment.

Check the advertisements in the SEARCHLIGHT section. If what you seek is not currently advertised, fill out the form below or use your company letterhead, giving complete specifications and mail to:

Searchlight Equipment Locating Service
Classified Advertising Division
CONTROL ENGINEERING
P. O. Box 12, New York 36, N. Y.

Your requirements will be brought promptly to the attention of the equipment dealers advertising in SEARCHLIGHT. You will receive replies directly from them.

SEARCHLIGHT Equipment Locating Service

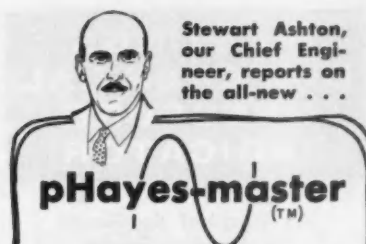
CONTROL ENGINEERING

Please help us locate the following:

NAME _____
TITLE _____
COMPANY _____
STREET _____
CITY _____ ZONE _____
STATE _____ 4/61

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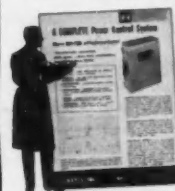
HERE AT LAST is a simple, compact, space-saving package that provides microsecond response for controlling power to electric furnaces... and for numerous other applications and processes where temperatures must be precisely regulated.

A TRANSISTORIZED UNIT, the new Hayes pHayes-master now replaces costly and bulky saturable core reactors, tubes, magamps, powerstats, etc. — with one, small, smartly-designed control unit!

VERSATILE, TOO... pHayes-master can be used with most proportioning type temperature instruments... handles up to 70 amp. capacities at 220 volts, with stepless control over the full 0-100% range. Highly accurate, pHayes-master provides instantaneous, straight-line response... completely without lag or hunting.

ECONOMY is another big advantage. The Hayes pHayes-master features a high power factor — expends only a fraction of the power source for control. Simple rugged construction and circuitry make it far easier and cheaper to install and maintain than conventional control devices.

These are just the highlights. If your equipment or process calls for close control of power for heat generation, get the complete facts on the all-new Hayes pHayes-master. Write for new Bulletin C-1, or tell us about your application requirements. — C. I. HAYES, INC., 938 Wellington Ave., Cranston 10, R. I.



C. I. HAYES, INC.

Established 1905

REGISTERED PATENT

It Pays To See Hayes for metallurgical guidance, lab facilities, furnaces, atmosphere generators, gas and liquid dryers, pHayes-master (TM) control units.

HASTINGS DIFFERENTIAL PRESSURE INDICATOR

(An Electrical dp Gauge
for Air and Gases)



CHOICE of **10** RANGES

.01" H₂O through 100" H₂O Full Scale

The Hastings Differential Pressure Indicator is composed of an indicator with power source unit and a dp tube. The indicator unit is available as shown or panel mounted, water proof and explosion proof housed and as control, alarm and recorder installations. The meter can be remotely located if desired.

The dp tube incorporates the patented Hastings compensated heated thermopile element which measures differential pressure directly in inches of water.

The Hastings Differential Pressure Indicator offers the following superior features:

- Extremely sensitive to low pressure differentials
- Rapid Response Time—less than 1/2 second
- Suitable for corrosive gases—Noble metal thermopile and nickel plated dp tube
- Versatile—Indicate, control, record—Remote
- Electrical rather than mechanical
- Readability from .0001" H₂O thru 100" H₂O
- Inexpensive—Less than most transmitter-type gauges
- Variety of Applications—Draft Gauge—Pressurized Enclosures—Mass Flowmeter—Process Control—Air Gauging—Leak Testing—Porosity Testing—Null Balance

Write or call for detailed specifications or for information on Hastings complete line of Vacuum, Pressure, and Flow Measuring Instruments.

HASTINGS-RAYDIST, Inc.

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A typical application of this unit is remote control of radar scanning equipment. **Weight: 3 $\frac{1}{2}$ oz.**



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In the smaller assembly (1" wide by 1.812" long) any gear ratio up to 1000:1 can be supplied. In the other assembly (1.281" wide by 1.859" long) gear ratios up to 4000:1 are available. Choice of size 8 rotating components may be made for either design.

Depending on materials and components, **weight: 4 to 6 oz.**

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Depending on materials and components, **weight: 6 to 12 oz.**



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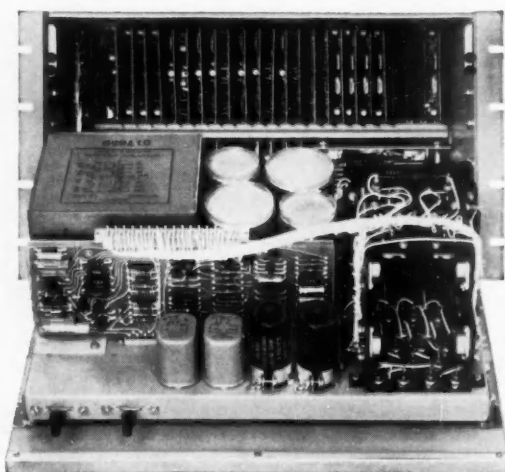
CIRCLE 234 ON READER SERVICE CARD





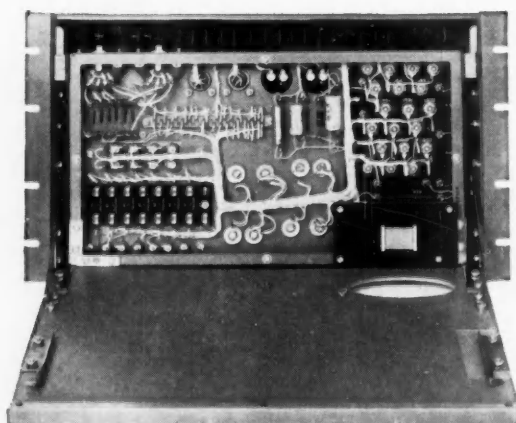


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